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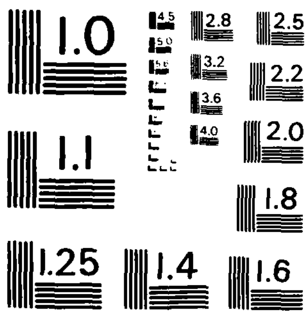

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Terrain analysis procedural guide for surface configuration

AD-A145 637

MARCH 1984

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U.S. ARMY CORPS OF ENGINEERS
ENGINEER TOPOGRAPHIC LABORATORIES
FORT BELVOIR, VIRGINIA 22060

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Topography	Factor Mapping,	Landform
Aerial Photography	Surface Roughness	Photo Interpretation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This procedural guide is an instructional manual for the use of the U.S. Army Terrain Analyst when preparing the following factor overlays: slope, landform, and surface roughness. These overlays are constructed from the analysis of the combined data extracted from literature, topographic maps, and aerial/LANDSAT imagery. A catalog section includes the descriptions of photo pattern, topographic map, and surface roughness data elements for thirty-seven typical topographic/geologic forms.

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PREFACE

This guide for Surface Configuration is one of a series of Analysis and Synthesis Guides to be produced. It is anticipated that after some modifications, the guides will be published as Department of Army manuals. For this reason, critical comments and suggestions are requested by the authors.

The published guides in this series are:

Number	Authors	Title	AD Number
ETL-0178	Jeffrey A. Messmore Theodore C. Vogel Alexander R. Pearson	TERRAIN ANALYSIS PROCEDURAL GUIDE FOR [illegible] (Report No. 1 in the ETL Series on Guides for Army Terrain Analysts)	AD-A068 715
ETL-0205	Theodore C. Vogel	TERRAIN ANALYSIS PROCEDURAL GUIDE FOR ROADS AND RELATED STRUCTURES (Report No. 2...)	AD-A090 021
ETL-0207	James Tazelaar	TERRAIN ANALYSIS PROCEDURAL GUIDE FOR [illegible] (Report No. 3...)	AD-A080 26[illegible]
ETL-0220	Alexander R. Pearson Janet S. Wright	SYNTHESIS GUIDE FOR CROSS-COUNTRY MOVEMENT (Report No. 4...)	AD-A084 [illegible]
ETL-0247	Roland J. Frodigh	TERRAIN ANALYSIS PROCEDURAL GUIDE FOR CLIMATE (Report No. 5...)	AD-A095 158
ETL-0254	Janet S. Wright Theodore C. Vogel Alexander R. Pearson Jeffrey A. Messmore	TERRAIN ANALYSIS PROCEDURAL GUIDE FOR SOIL (Report No. 6...)	AD-A107 0[illegible]8
ETL-0263	James Tazelaar	SYNTHESIS GUIDE FOR LINES OF COMMUNICATION (Report No. 7...)	AD-A104 29[illegible]
ETL-0285	Jeffrey A. Messmore	TERRAIN ANALYSIS PROCEDURAL GUIDE FOR DRAINAGE AND WATER RESOURCES (Report No. 8...)	AD-A118 318
ETL-0283	Robert A. Falls	SYNTHESIS GUIDE FOR OBSTACLE SITING (Report No. 9...)	AD-A118 [illegible]
ETL-0311	James Tazelaar	TERRAIN ANALYSIS PROCEDURAL GUIDE FOR RAILROADS (Report No. 10...)	AD-A12[illegible] [illegible]
ETL-0344	Jeffrey A. Messmore	SYNTHESIS GUIDE FOR RIVER CROSSING (Report No. 11...)	

This study was initiated under DA Project 4A762707A855, Task C, Work Unit 21, "Military Geographic Analysis Technology." The current designation is QG48550C21.

This study was done under the supervision of A.C. Elser, Chief, MGI Data Processing and Products Division; and Messrs. K.T. Yoritomo, W.E. Boge, and B.K. Opitz, Directors, Geographic Sciences Laboratory.

Colonels Daniel L. Lycan, CE, and Edward K. Wintz, CE, were the Commanders and Directors and Messrs. Robert P. Macchia and Walter E. Boge were Technical Directors of the Engineer Topographic Laboratories during this report preparation.

The authors wish to express their appreciation to Messrs. Robert F. Falls and Lawrence P. Murphy who contributed greatly to Section 4 of this report.

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UNIT OF MEASUREMENT

[illegible] Units of Measurement used in th[illegible] to metric (SI) as follows:

MULTIPLY	BY	TO OBTAIN
inches	[illegible]	millimeter
feet	30.48	centimeter
miles	1.6093	kilometer
acres	0.40[illegible]	hectare
ounces	28.[illegible]	gram
gallons	3.78[illegible]	liter
Fahrenheit degrees*	5/9	degrees (Celsius, Kelvin)

---

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula:

$$C = (5/9)\ (F-32)$$

To obtain Kelvin (K) readings, use formula:

$$K = (5/9)\ (F-32) + 273.15$$

TERRAIN ANALYSIS PROCEDURAL GUIDE FOR SURFACE CONFIGURATION

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TERRAIN ANALYSIS PROCEDURAL GUIDE FOR SURFACE CONFIGURATION

1. INTRODUCTION

The capability to move men and materials from one point to another in an operational area is an essential ingredient of combat power and is often decisive to the outcome of a battle. Planning and maneuvering are dependent not only on the existence and knowledge of adequate lines of communication in a combat zone; knowledge of the terrain is also essential. The commander must have accurate intelligence on the surface configuration of the terrain, including slope, landform, and surface roughness. This information is important because the type of landform, steepness of slope, and roughness of the terrain surface influence cross-country mobility; indeed, consideration of these terrain conditions is necessary for proper maneuver planning.

1.1 Purpose.

This Terrain Analysis Procedural Guide for Surface Configuration provides terrain analysts with the methods for preparation of factor overlays for slope, landform, and surface roughness based upon the analyses of literature, maps, and aerial imagery.

1.2 Background.

The first step in the generation of terrain intelligence and preparation of special purpose products is the reduction of data contained in a variety of source materials to a uniform scale and format. This process of extracting data from available sources, then reducing and recording it in the desired form, is the most laborious and time-consuming step in the production cycle. If this process is delayed until a production requirement is imposed, response time will be appreciably increased. However, if the extraction, reduction, and recording are performed in advance and the preformatted results are maintained as one component of the thematic graphic data base (TGDB), the time required to respond to a production requirement can be greatly reduced.

The concept for preformatting data in the form of factor overlays registered to standard military topographic maps is illustrated in figure 1.1. Under this concept, data are extracted from various source materials and recorded on factor overlays and supporting data tables. Separate overlays and tables are prepared for each map sheet and major terrain subject or data field, e.g., slope, landform, surface roughness, drainage, and water resources. The overlays are produced and maintained on acetate or mylar that will accept ink or pencil and permit erasing. It is not anticipated that all required information will be available during the initial preparation of a factor overlay. Lack of complete information, however, will not preclude preparation of the overlay. The factor overlay concept envisions the systematic recording of data as it is acquired

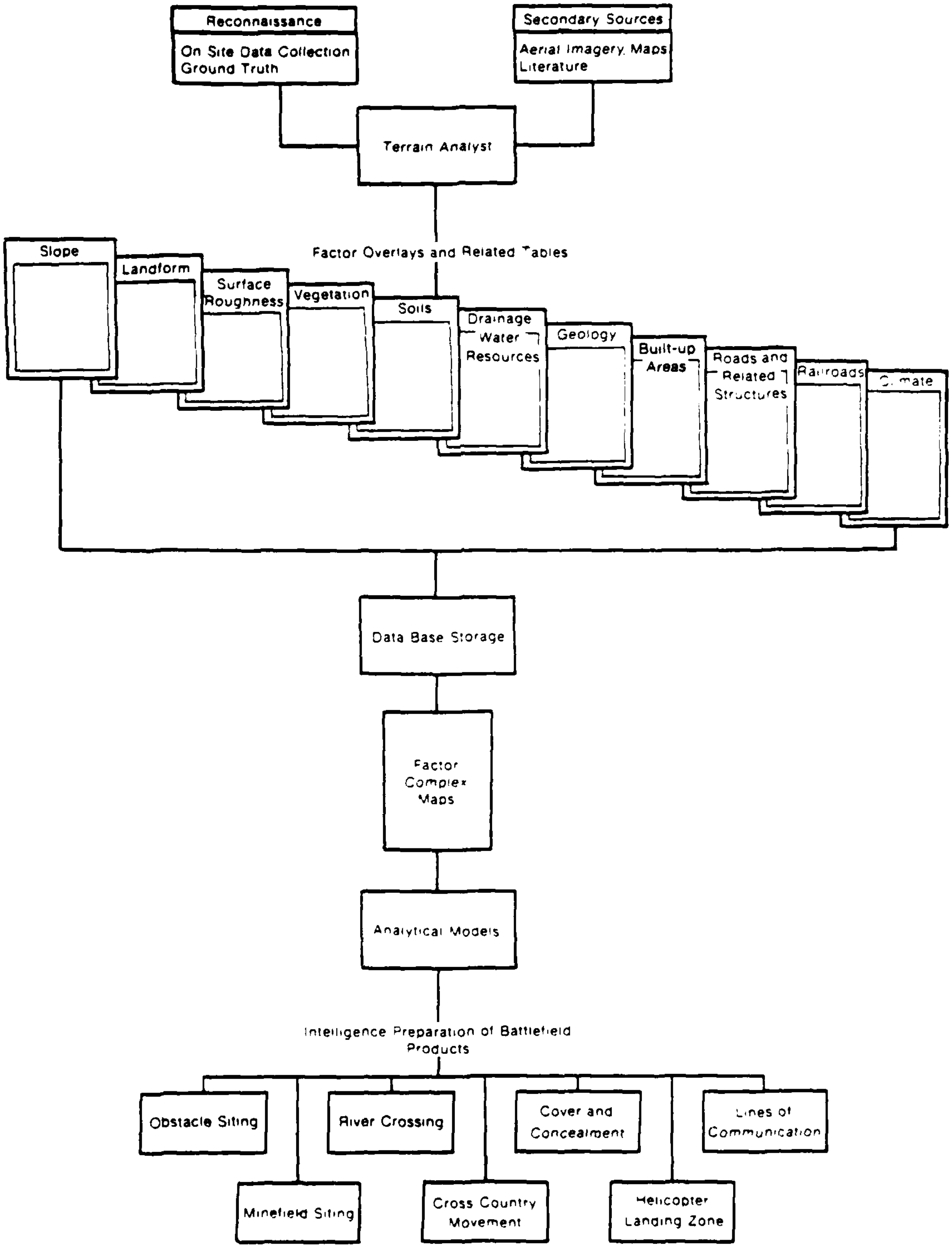


Figure 1.1 Production and Use of Factor Overlays and Data Tables.

and the accumulation of data through frequent revision and update.

The factor overlay approach to terrain analysis is illustrated in figure 1.2. As shown, overlays are used in various combinations to generate factor complex maps, which become, in effect, the manuscript for special purpose products or topic graphics, such as cross-country movement and Intelligence Preparation of the Battlefield (IPB) graphics. The data elements appearing on the complex maps become inputs for analytical performance prediction models. For example, preparation of a cross-country movement (CCM) map would begin by combining the overlays for slope, soil, surface roughness, and vegetation into a complex map. Those data elements affecting CCM, i.e., slope, stem spacing, stem diameter, soil strength, etc., are then recorded in the complexed areas of the map. When processed by analytical methods, these elements are transformed into vehicle speed predictions for each complexed area.

This procedural guide for surface configuration provides for the production of three TCDF overlays: slope, landform, and surface roughness (figures 1.3-1.5) and is organized in the following manner. Section 2 identifies and describes available SOURCE MATERIAL from which factor overlays can be constructed by analysis of combined data extracted from maps, aerial imagery, and literature. This is followed by a PROCEDURAL OUTLINE section that provides an introductory overview of the major steps required to prepare the surface configuration factor overlays. The next section, SLOPE ANALYSIS METHODS, describes the detailed procedures and methods the analyst uses to produce a slope factor overlay. Section [illegible], LANDFORM ANALYSIS METHODS, provides the instructions for extracting landform data elements from literature, military and/or topographic maps, and airphotos. The SURFACE ROUGHNESS ANALYSIS METHODS section describes in detail how an analyst can arrive at a surface roughness factor (SR) value based upon quantitative measurements taken from topographic maps and/or aerial photos. Section 7, [illegible], provides descriptions and examples of photo pattern, topographic map, and surface roughness data elements for 3[illegible] typical topographic-geologic forms. Flow diagrams are also included to illustrate the relationship of origin to form for each of the Glacial, Fluvial, Eolian, Sedimentary Rock, Igneous, and Metamorphic landforms illustrated in section 7. The Bibliography provides a list of references that were used in preparing this guide. Appendix A provides useful guidelines to assist terrain analysts in preparing terrain factor overlays for slope, landform, and surface roughness. Appendix B provides topographic maps, photos, and other supplementary data that have been used and cited as examples in this document, which should be useful to terrain analysts.

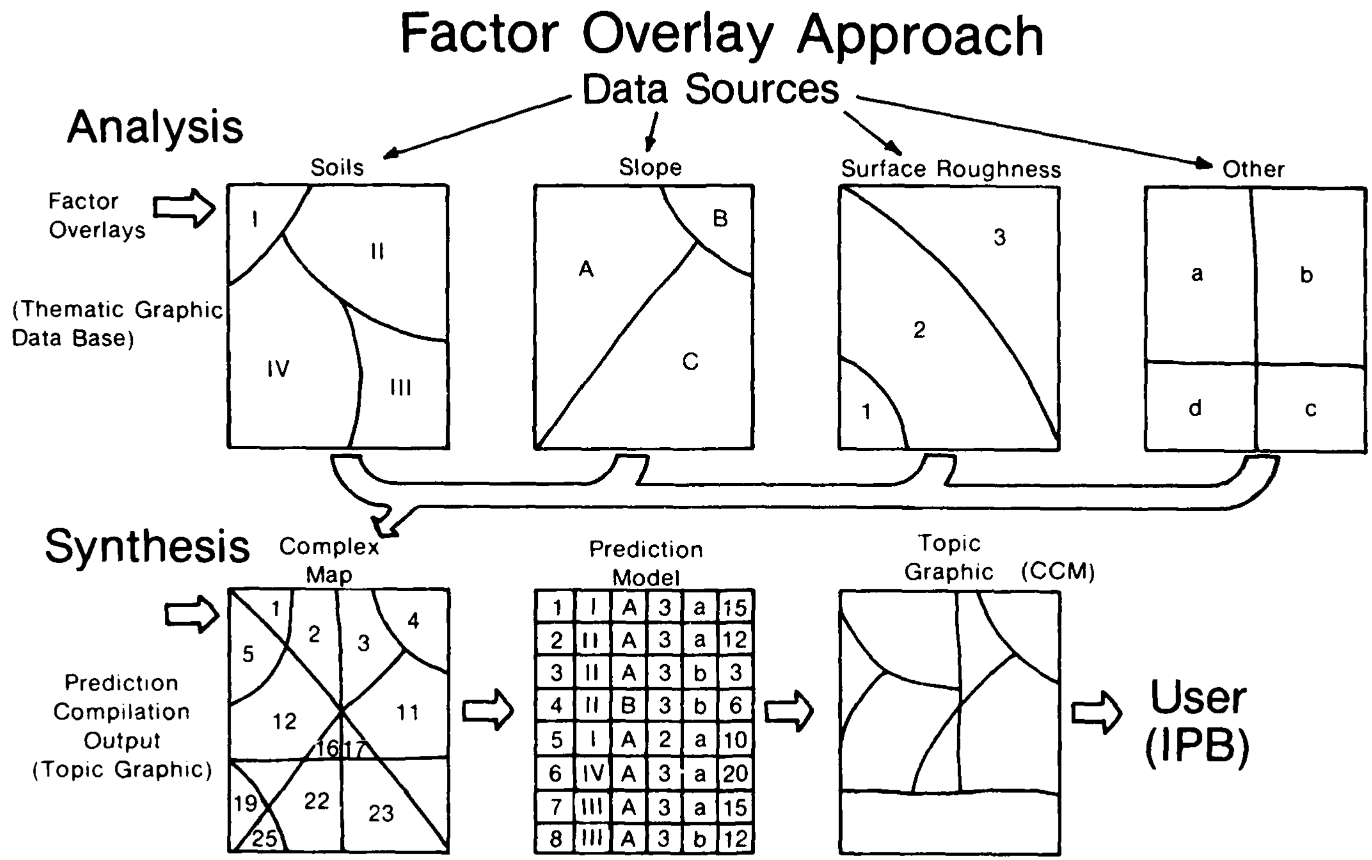
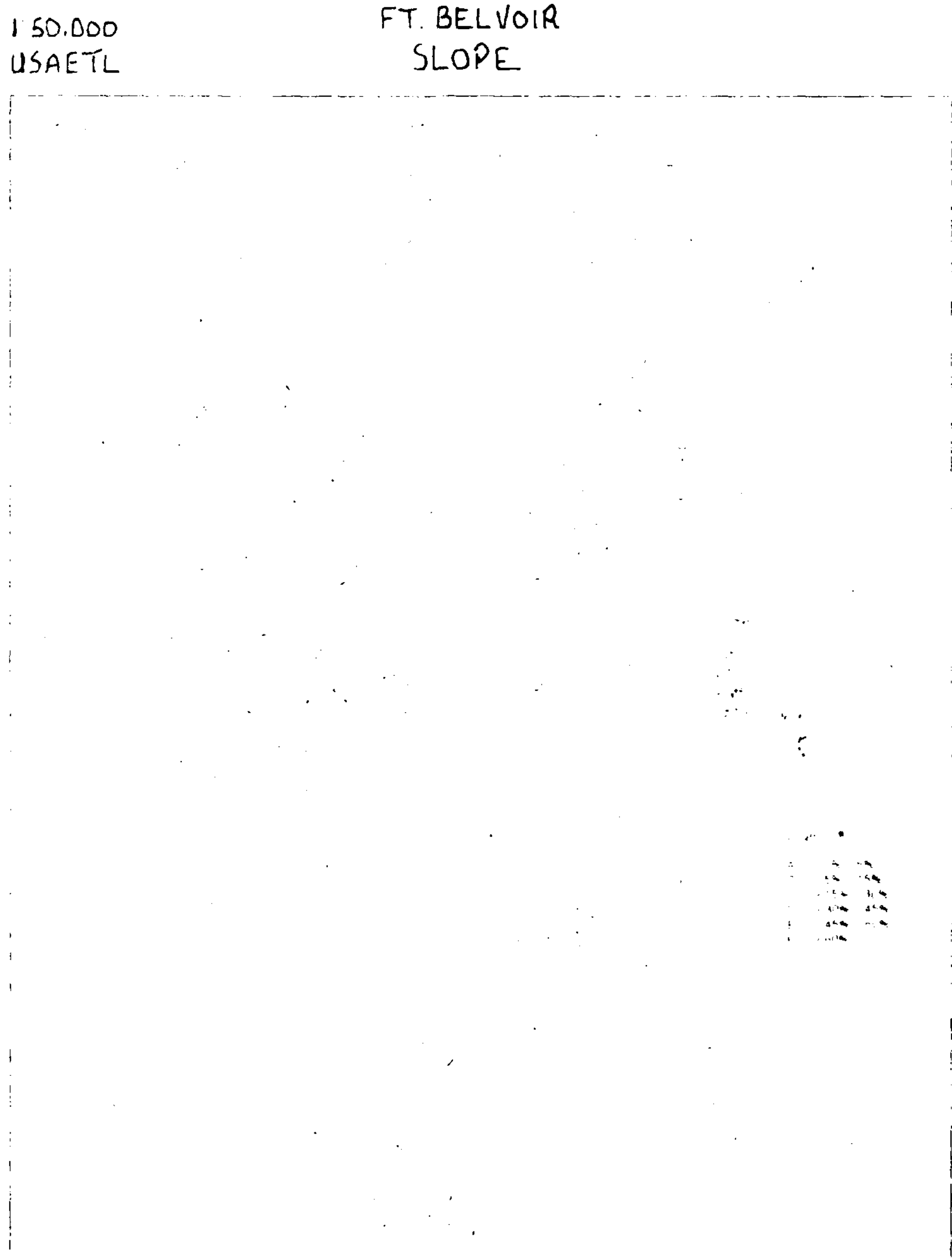


Figure 1.2. Factor Overlay Approach.



*The ranges for slope [illegible] GCM and are shown here for illustration purposes [illegible] ETL-022[illegible]

Figure 1 3. Slope Factor Overlay

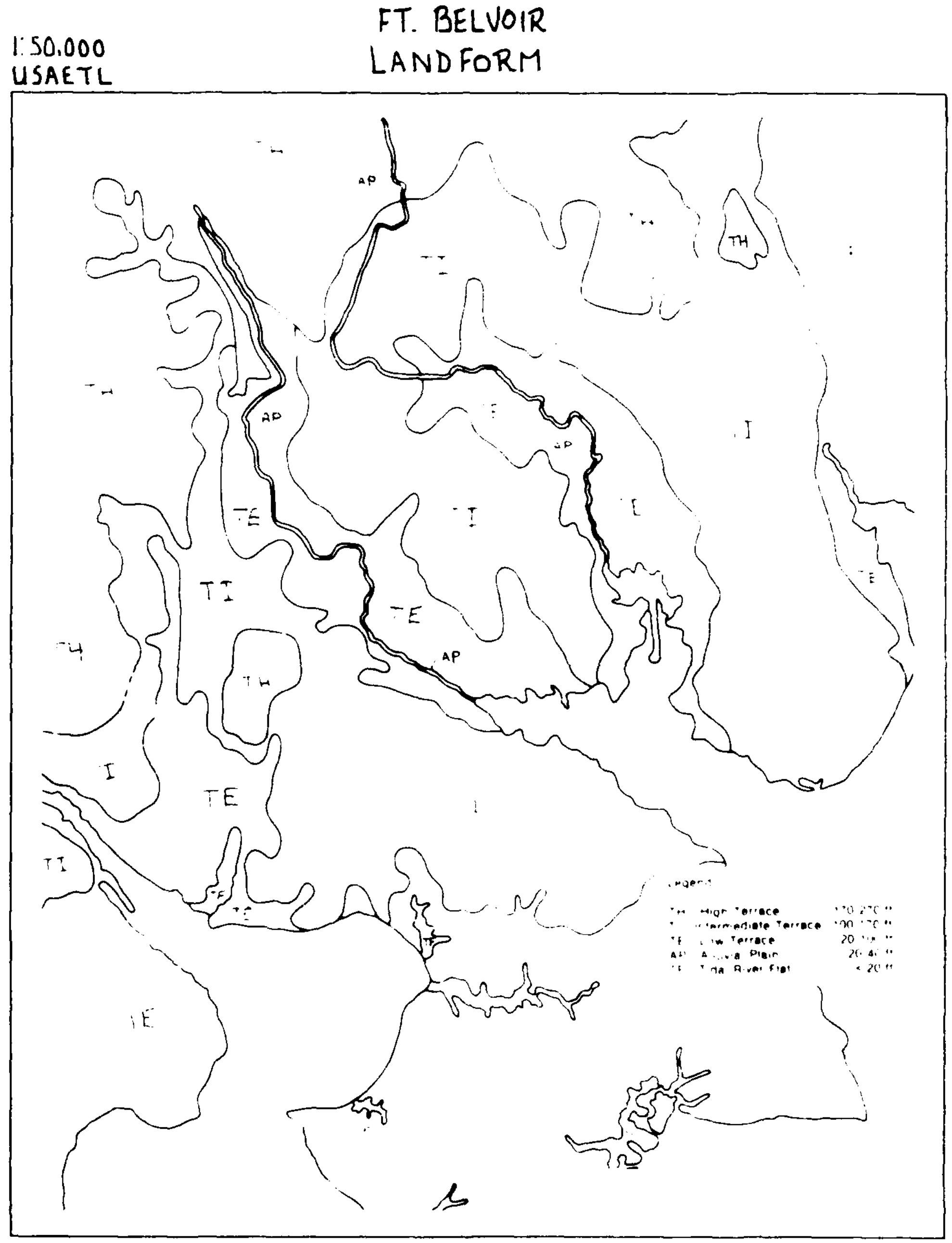


Figure 1.4. Landform Factor Overlay.

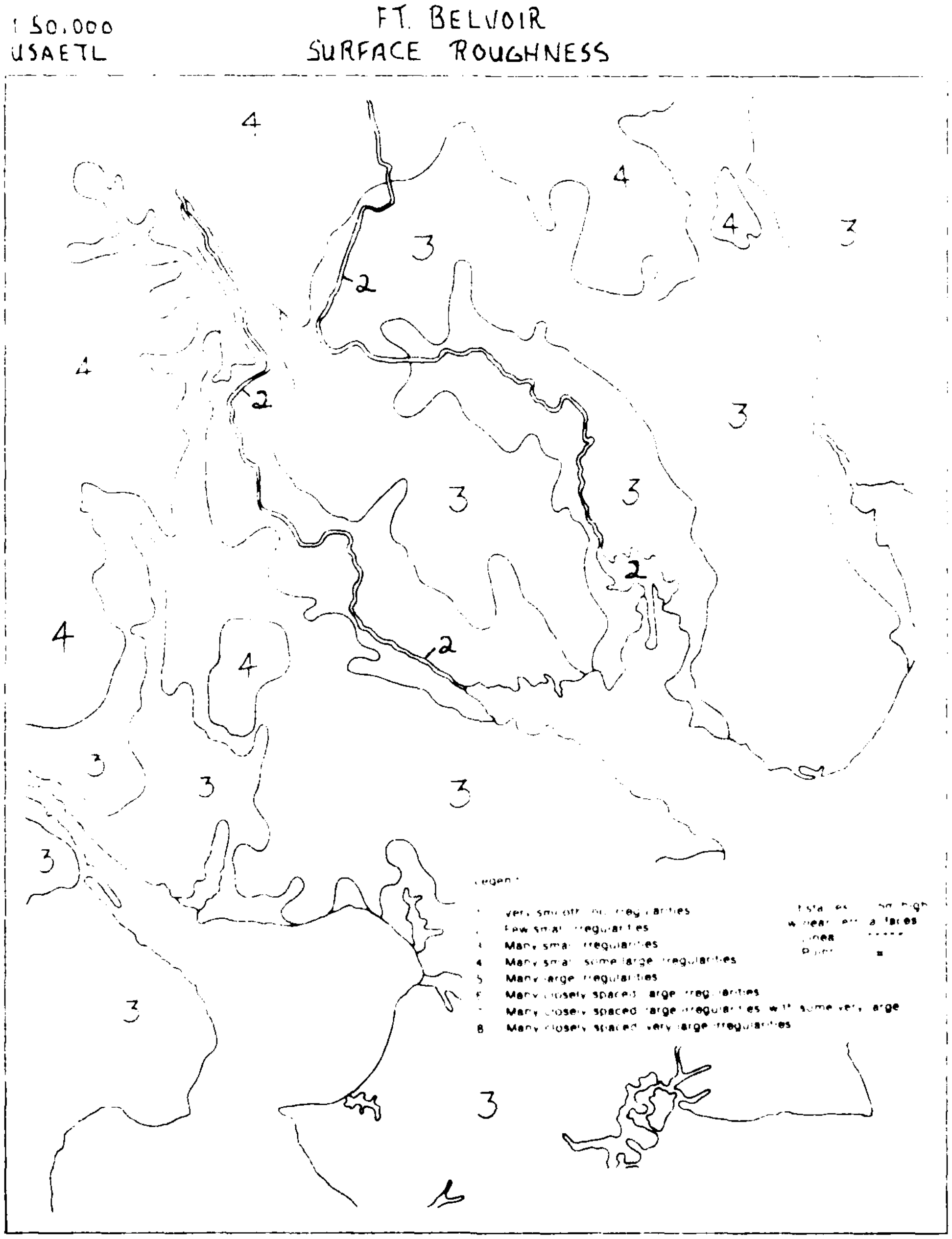


Figure 1.5. Surface Roughness Factor Overlay.

2. SOURCE MATERIALS

The terrain analyst produces the surface configuration overlays with the aid of available source materials: literature, maps, and aerial imagery. The adequacy of these source materials will vary from area to area, and it is often necessary to use source materials prepared in countries foreign to the country being studied. Even poor quality sources may have to be used. As better sources become available, first generation overlays will be revised to incorporate the additional information. In some areas there may be no sources readily available; in this case, it will be necessary to initiate a collection effort to obtain the source materials. The analysis process begins by reviewing the data base materials.

2.1 Review Data Base Materials.

Review the data base file indexes to locate source materials dealing with the geographic area of interest. Useful materials include current 1:24,000 and 1:50,000 scale topographic maps; regional studies on landforms, geology, and geomorphology; reconnaissance and image interpretation reports; and aerial photography at scales preferably ranging from 1/20,000 to 1/40,000.

Review the materials obtained above and determine whether they are adequate for generation of the surface configuration factor overlays. If they do not provide sufficient detail, or in the case of aerial imagery, sufficient areal coverage, initiate action to collect additional materials. Start the analysis with materials on hand.

2.2 Acquisition of Source Materials.

In general, all items that provide the analyst with landform information for the geographic area of interest are source materials. Locating these materials will often require a tenacious and comprehensive search of university and city libraries, government agency files, university research data, and construction company files.

2.3 Literature.

This source of information is nearly unlimited in quantity, scope of subject matter, and coverage of geographic regions of the world. Unfortunately, information available from this source is often too general to be of real use to the terrain analyst. Most useful literature contains information related to the specific geographic area under study and provides an understanding of the physiographic divisions and major topographic forms found in the area. For this reason, area-specific literature should be reviewed by the analyst as background source material. The reports, articles, and textbooks that supply the specific information needed by the analyst are obtained from local government agencies, universities, libraries, and commercial mapping companies.

2.4 Maps.

In general, there are three major map types available to the terrain analyst that can be employed to obtain the data required for compilation of the surface configuration overlays. These are topographic maps, surface configuration maps, and landform distribution maps.

2.4.1 Topographic Maps. Standard topographic maps that portray elevation and planimetric data are available at numerous scales. These scales vary from large scale at 1/24,000 to small scale at 1/1,000,000. As would be expected, the larger the map scale, the smaller the contour interval and the greater the amount of information that can be extracted. Specific topographic data element information derived from this source includes form, special features, land use, and texture (contour line distribution).

2.4.2 Surface Configuration Maps (1:1,000,000). This type of map can be found in any general geography text or atlas and usually will depict very broad categories of surface configuration. In general, these maps and associated descriptions will not provide the type of detail that is required for specific landform identification. They should be reviewed by the analyst, however, for familiarization with the geographic area of interest.

2.4.3 Landform Distribution Maps. These maps are produced under a variety of names depending on the type of data they present. Maps of this type produced by various government and private agencies are found listed as landform or physiographic maps. Colleges and universities also produce detailed maps as part of theses from graduate degree programs. In general, maps found in theses are characterized by their large scale and detailed information content. Because they are produced for a limited function and area, they are difficult to locate and reproduce. When available, however, they provide an excellent source of information and can be used by the terrain analyst in the interpretation of aerial imagery by extrapolating the information provided by the map to areas of terrain not covered by the map. The analyst should query local government agencies and universities located in the geographic region of interest.

2.5 Aerial Imagery.

As used in this procedural guide, aerial imagery includes imagery obtained by aerial cameras and electro-optical scanners (primarily LANDSAT). Aerial imagery can provide some, if not all, of the information required for the surface configuration overlays. The accuracy and amount of detail that can be obtained will depend on the season and the scale of the imagery as well as on the skill and knowledge of the analyst.

Aerial cameras expose film in such a manner that each exposure overlaps the preceding one by approximately 60 percent with adjacent flight lines overlapping 30 percent. This photo overlap procedure affords the analysts an opportunity to visualize the terrain in three dimensions when viewing the photography stereoscopically. For correct analyses, the analyst should be apprised of the season of year, sun angle, weather conditions, and filter combinations through which the film was exposed. The best photos to use are 9" x 9" prints at 1:20,000 or larger scale.

LANDSAT prints are an excellent source of regional analysis information. Winter scenes should be ordered during the source material acquisition phase of the terrain analysis. For ordering and interpretation purposes, the following specifications should be adhered to: (1) bands 5 and 7, (2) 1:250,000 scale, (3) black and white prints, (4) less than 10 percent cloud cover, and (5) most recent acquisition date.

2.6 Suggested Reading.

Since the Army operates worldwide, detailed terrain information is needed worldwide. To obtain this information, the analyst must have a basic knowledge of the origin and distributions of landforms and the factors producing them within different world regions. It is suggested that the analyst read and review the military manuals and texts that are available. Some pertinent texts are listed below:

ETL-0178 Procedural Guide for Vegetation
ETL-0207 Procedural Guide for Geology
ETL-0285 Procedural Guide for Drainage and Water Resources
ETL-0254 Procedural Guide for Soils

Further, the analyst should review and maintain as reference material the following texts:

Terrain Analysis, 2nd Edition
Douglas Way
McGraw Hill Book Co.
New York, NY

Atlas of Landforms, 2nd Edition
H. A. Curran, et al.
John Wiley and Sons, Inc.
New York, NY

FM 30-10, Military Geographic Intelligence (Terrain)
FM 21-26, Map Reading
TM 5-545, Geology
TM 5-818-2, Soils and Geology
TM 5-818-4, Soils and Geology
EM 1110-2-1906, Laboratory Soils Testing
TM 5-330, Planning and Design of Roads, Airbases, and Heliports in the Theatre of Operations
FM 21-33, Terrain Analysis

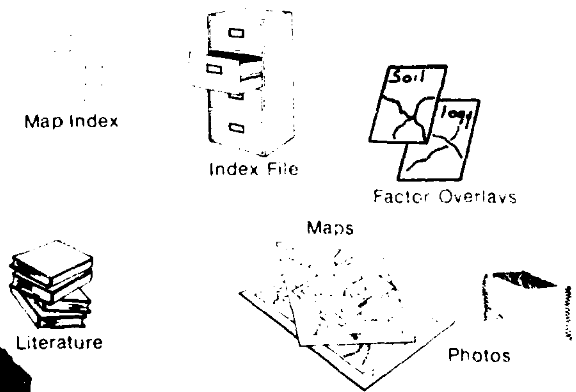
3 [illegible] NE

[illegible] section provides an overview of the analysis [illegible] used [illegible] Slope, Landform and Surface [illegible] and the [illegible] sequence in which they are [illegible]. [illegible] organized into four subsections: 3.1 Preparatory Steps, 3.2 Slope, [illegible] Landform, [illegible] 3.4 S[illegible]

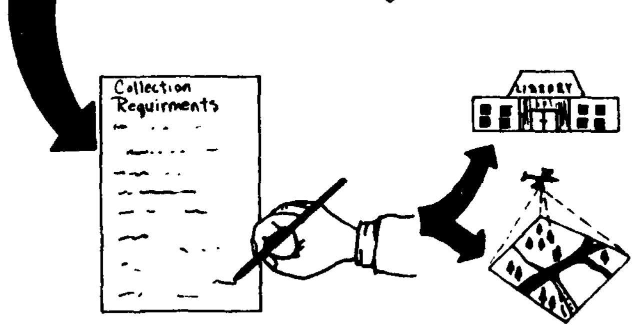
3.1 PREPARATORY STEPS

3.1.1 Determine which overlays are needed based on requirements. If slope overlay is only needed, proceed to slope overview as a comprehensive data search is not required. If other overlays are needed, proceed to next step.

3.1.2 Assemble [illegible] source materials. Select materials which provide background information and help in the process of characterizing the landforms, geology, vegetation, drainage, soil and climate of the area. If available, previously prepared factor overlays on these subjects should also be obtained from the data base.



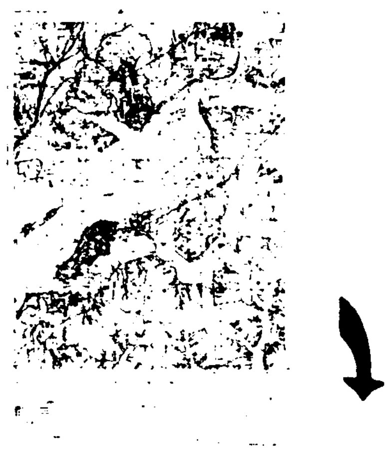
3.1.3 Conduct a preliminary evaluation of source materials and note any information that is missing or inadequate. Submit collection requirements to supplement available source materials.



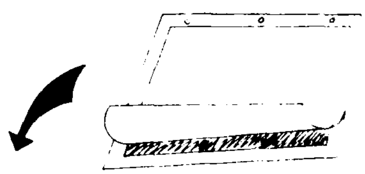
3.2 SLOPE

3.2.1 Topographic Map Technique

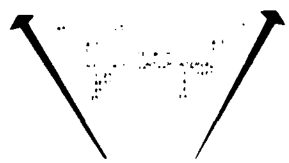
3.2.1.1 *Obtain a topographic map of the area of interest with a scale of 1:50,000.* If this scale cannot be obtained, the final slope overlay must be adjusted to 1:50,000



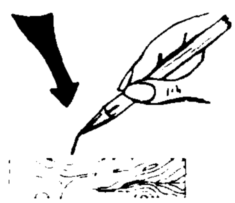
3.2.1.2 Lay a sheet of clean mylar over the topographic map. Determine scale and contour interval (C.I.)



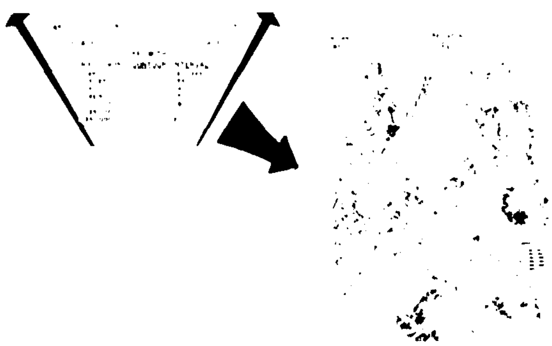
3.2.1.3 Select a slope calculator that was constructed for the scale and contour interval of the map used, and that has the required scope categories. normally these are 0-3%, 3-10%, 10-30%, 30-45%, 45-60%, and > 60%. If a suitable slope calculator is not available, construct one. Use the general formula below to determine line spacing for each slope category.

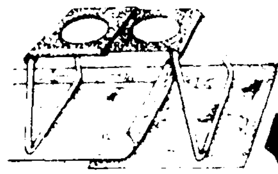


$$\text{Line spacing} = \frac{100}{\%\ \text{slope}} \times \text{C.I.} \times \text{map scale}$$

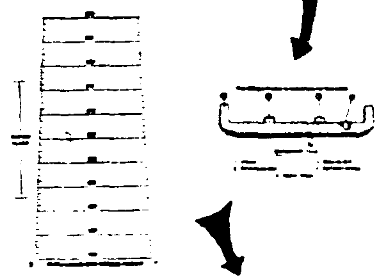


3.2.1.4 Start the slope analysis in upper left hand corner of the map and determine map areas whose slope (*contour line spacing*) matches the 3% slope category on calculator. Include map areas that have slopes less than 3% then bound all areas whose slope is 0-3% and identify them. Continue this analysis for all slope categories. Work until all areas have been bounded and identified.





[illegible]



[illegible]

[illegible] Measure [illegible] distance [illegible]

[illegible] Calculate slope

[illegible]

[illegible]

3.2.2.6 Slopes for several areas of the map are measured. Then categories of slope are determined.

3.2.2.7 Prepare factor overlay. Draw boundaries to depict separation between several slope categories.

3.3 LANDFORM

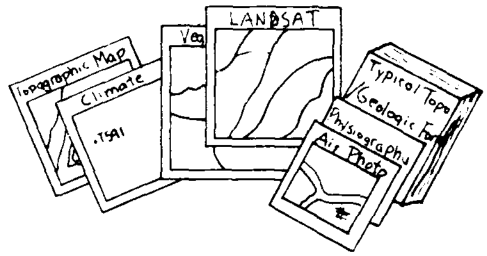
3.3.1 Primary Source Materials

a. Topographic Maps

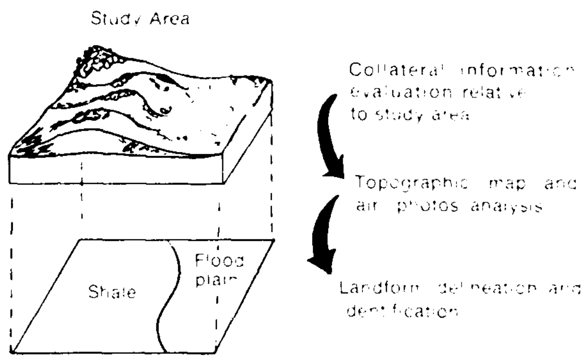
b. Aerial and LANDSAT Imagery

c. Collateral Information Data Base

d. Section 7. Typical Topographic Geologic Forms

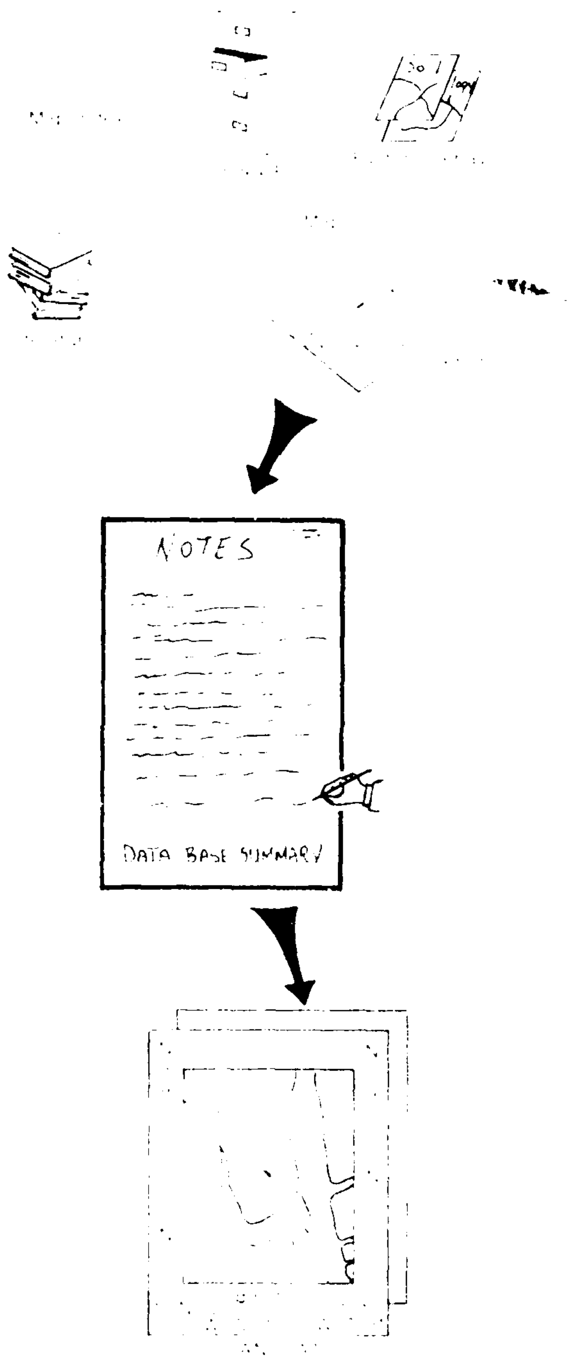


3.3.2 The first step in the landform analysis involves a thorough evaluation of collateral information to develop the data base for the study area. This background knowledge forms the broad foundation from which the detailed analysis of topographic maps and air photos can proceed to landform delineation and identification.

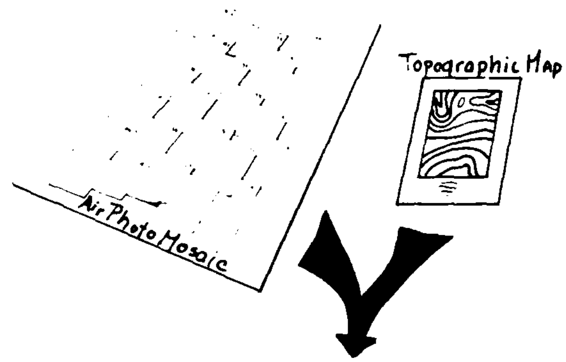


3.3.3 The purpose of collateral information data base evaluation is to answer such questions as these:

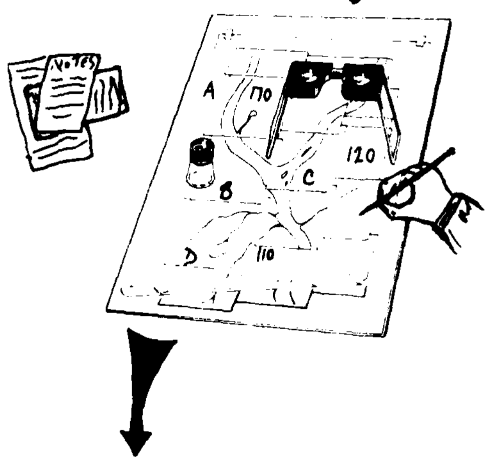
- What type of landforms can be expected in study areas?
- What type of surface materials can be expected in the study area?
- What is the origin of these surface materials? Are they from rock? Were they deposited by water, glacial or other activity?
- What type of drainage patterns will most likely be found?
- Is there a landform distribution pattern that can be ascertained in the study area?


NOTES
DATA BASE SUMMARY

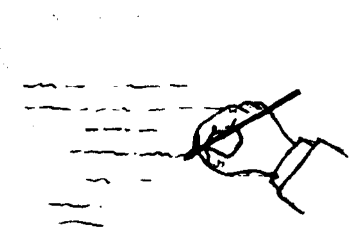
3.3.6 *Study the photo index. Order air photos needed for coverage of the study areas. Lay out a mosaic of air photos and cover with a sheet of clear mylar. Use the topographic map to determine the elevation of selected areas on the air photo mosaic. Place elevations on the overlay in locations of interest.*



3.3.7 Study photos stereoscopically. Draw preliminary landform boundaries on the overlay keeping notes from data base and elevation information close at hand for reference. Label each bounded area A, B, C, etc.



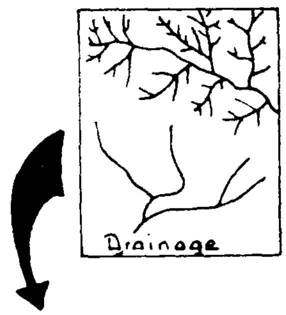
3.3.8 Using photo analysis supplemented by descriptive information from 1:250 000 LANDSAT prints, fill in a photo pattern data element table for each anticipated landform in the study area.



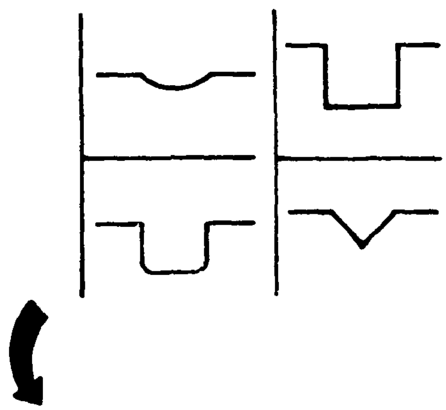
3.3.9 Analyze, in turn, each of the subject areas identified in the following paragraphs. Record this information in the Photo Pattern Data Element Table described in the preceding paragraph. A separate Photo Pattern Data Element Table should be used for *each anticipated landform in the study area.*

a. *Form: Topographic Position.* Study topographic expression; observe elevation data as depicted by contour lines on the topographic map. Record the elevation range the landform appears to occupy. The range should correspond to the elevation range noted from the data base. Describe relief form.

b. Drainage. Study drainage patterns, construct a separate drainage overlay or use an existing drainage map, and classify the patterns. Record a description and type of pattern in the photo pattern data element table.



c. Gully Characteristics. Study characteristics and classify according to cross section and gradient. Record description in photo pattern data element table for each landform.

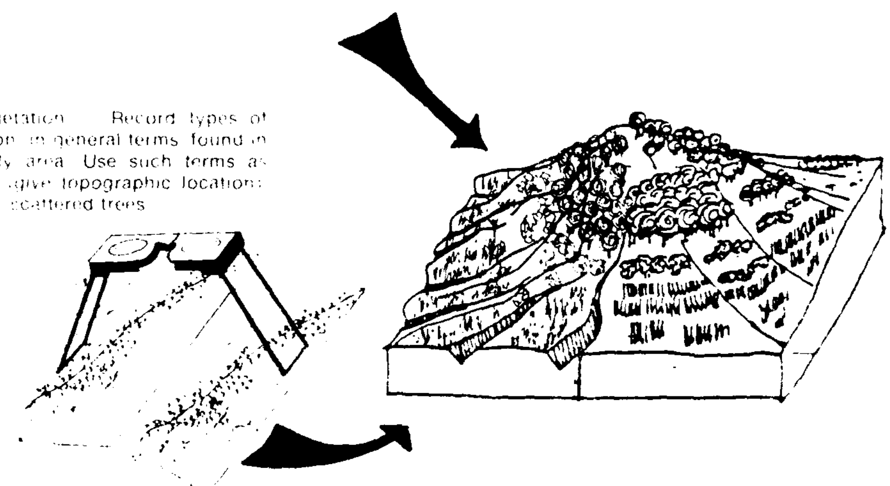


d. Special Features. Record unusual features observed in the photo such as catsteps, pinnacles, sink holes, terracettes, etc.

e. Color (Photo Gray Tones). Study the gray tones depicted on the photos and characterize the distribution of gray tones within the area. If possible, separate the patterns. Record these descriptions as mottled, light on ridges, or dark gray tones, etc.

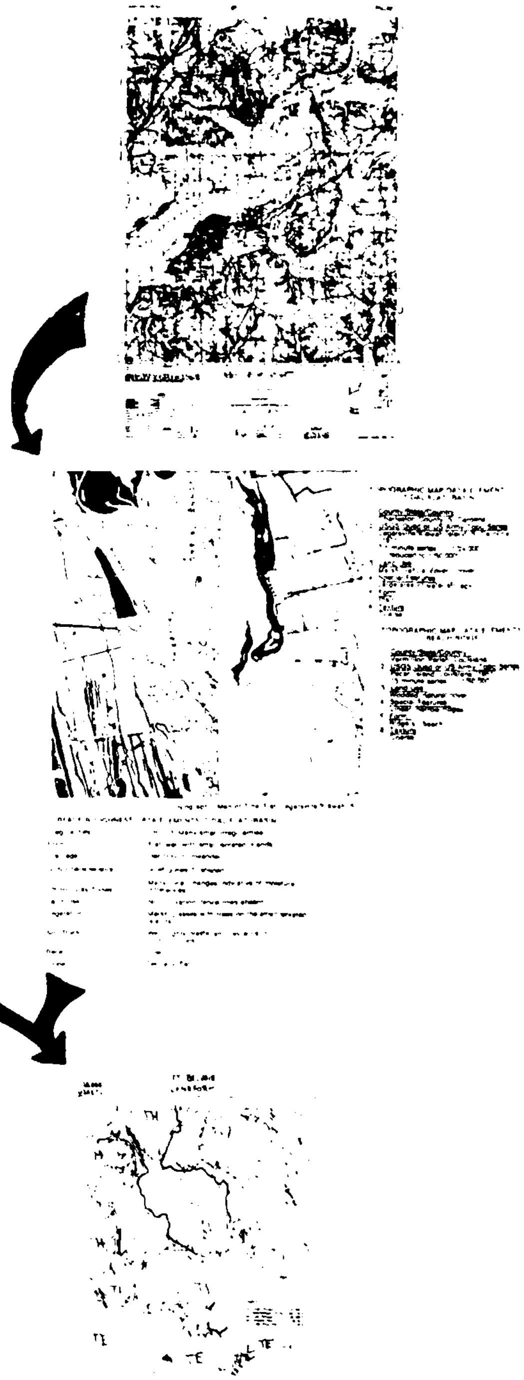
f. Land Use. Study land use patterns found in the area of interest. Characterize the patterns in general terms such as agriculture, wood lots, strip cropping, gravel pits, etc. Consult a topographic map for assistance and record findings.

g. Vegetation. Record types of vegetation in general terms found in the study area. Use such terms as forested (give topographic locations), marshes, scattered trees.

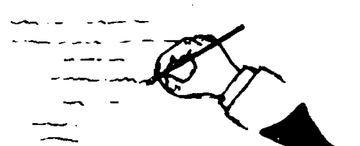


3.3.10 As questions arise, especially in relation to elevation [illegible] information [illegible] topographic map of the study area. [illegible] the map [illegible] information [illegible] study area.

- [illegible]
- [illegible]
- [illegible] features [illegible]
- [illegible]
- [illegible]



3.3.11 After recorded descriptions [illegible] pattern data [illegible] table for each suspected landform. Compare this information along with that derived from the topographic map with reference materials in Section 7 of this guide. Identify bounded areas as specific landforms. Adjust boundaries as necessary.



3.3.12 [illegible] landforms with appropriate [illegible] Identify approval [illegible]
The [illegible] terrace
[illegible]

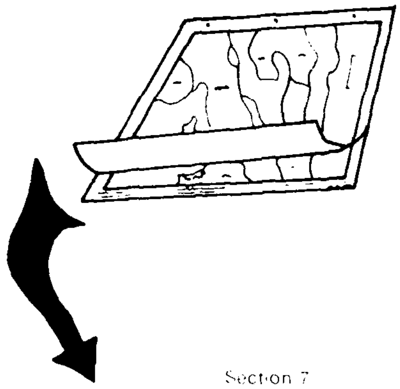
3.3.13 If a field check procedure is possible, go to the study area (ground or aerial reconnaissance). Verify landforms [illegible]

3.4 SURFACE ROUGHNESS

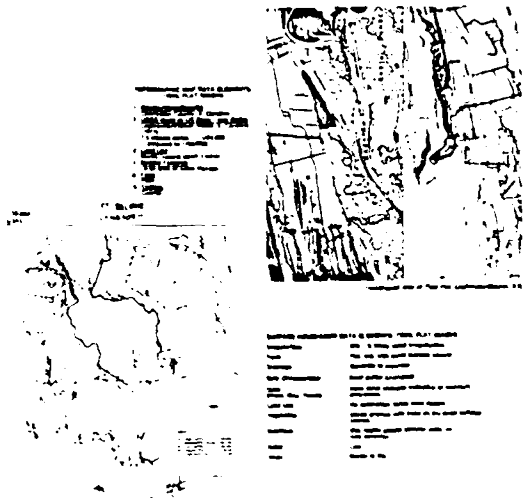
There are two approaches the analyst can take in arriving at the surface roughness index (SRI) needed for each landform. The first approach is a faster method, but it is inherently less quantitative and relies heavily upon the experience of the analyst. The second approach is more systematic, more quantitative, requires less experience, but is more time consuming. As the analyst gains familiarity with this guide, the first approach will probably be the most usual approach with the quantitative method used in special situations.

First Approach

3.4.1 Place a sheet of clear mylar over the completed landform overlay.



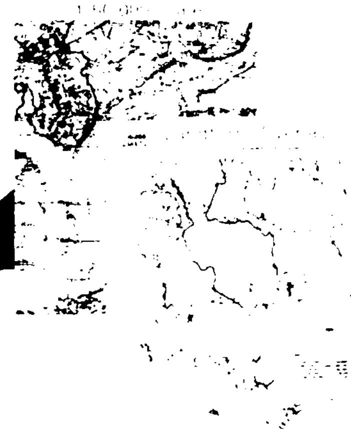
3.4.2 Conduct a surface roughness analysis for each landform on the overlay. Consult section seven (7) of this guide and attempt to locate a match for each landform outlined on the overlay. If a landform on the overlay is not contained in section 7, use a landform that most closely approximates the surface roughness of the landform of interest. If the landform is in section 7, consider using *the landform's surface roughness index given as one of the "surface roughness data elements".* If justified, the SRI value from section 7 can be adjusted ± 1 depending on surface conditions. If the SRI value is off by more than ± 1, it may be that the landform has been wrongly identified; then approach #2 should be used.



3.4.3 [illegible]

[illegible] Approach

This approach consists of two [illegible] methods [illegible] employs the topographic map as its source [illegible]

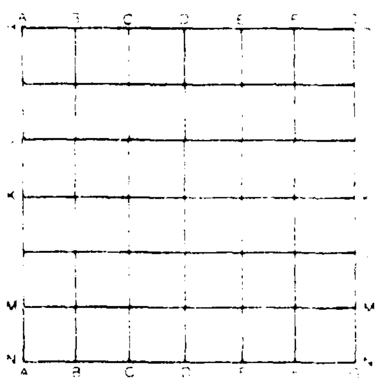


[illegible] Map [illegible]

3.4.1 [illegible] topographic [illegible] study area and use [illegible] overlay to locate landforms [illegible]

3.4.2 [illegible]

[illegible]



[illegible]

[illegible]

3.4.4 Use the surface roughness equation below to calculate an SRI for each landform. Record these values on a separate surface roughness overlay.

$SRI = E/D\sqrt{A+C} + 0.1\,(B)$

A Number of contour lines per 1.2 km

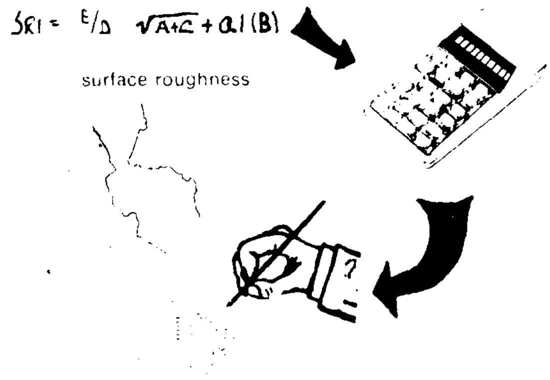
B Number of fence rows per 1.2 km

C Number of contour bends per 1.2 km

D Contour bend wavelength (cm)

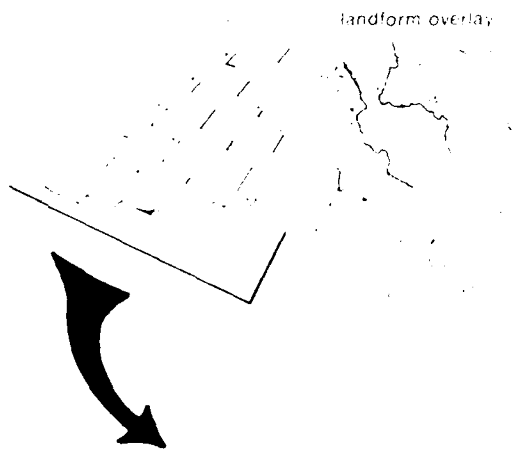
E Contour bend amplitude (cm)

Clean up overlay and add margin information as necessary.



Airphoto Analysis

3.4.5 Prepare an airphoto mosaic of the study area (scale 1:40,000 or larger). Place the landform overlay on the mosaic to locate landform boundaries. Select a representative stereo-pair from the photos of each landform on which to perform measurements.



3.4.6 Construct a grid on clear mylar with cells that correspond to a standard linear ground distance of 1.2 km for the scale of photography being used.

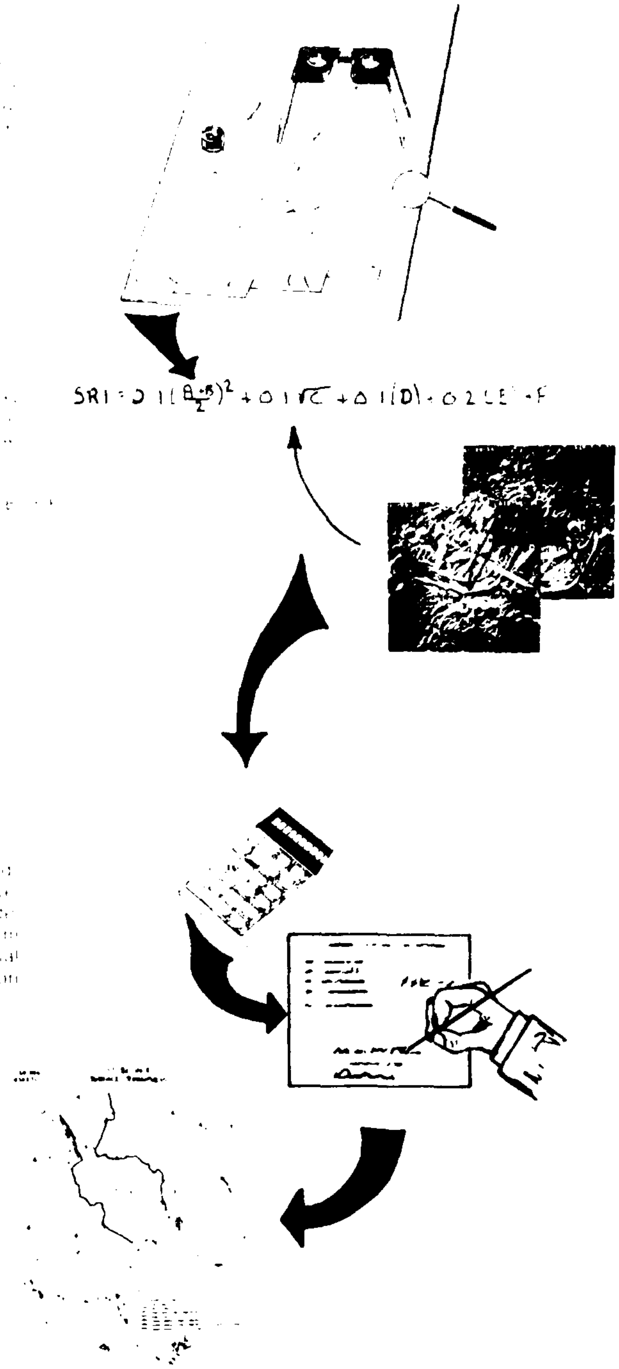
[illegible]

3-4-8 Enter the photo measurements of the surface roughness equation below. Continue for each factor delineated on the overlay.

SRI = [illegible]

A. Number of contour bends per 1.2 km.
B. Number of ditches less than 3m wide per 1.2 km.
C. Number of point obstacles per 1.2 km.
D. Number of fence rows per 1.2 km.
E. Number of tonal changes per 1.2 km.
F. Number of [illegible] obstacles per 1.2 km.

3-9 Calculate an SRI for each area [illegible] using the information at left. After all calculations are complete, assign an SRI value to each landform on the overlay, clean up the final overlay, and add marginal information as necessary.



4. SLOPE ANALYSIS METHODS

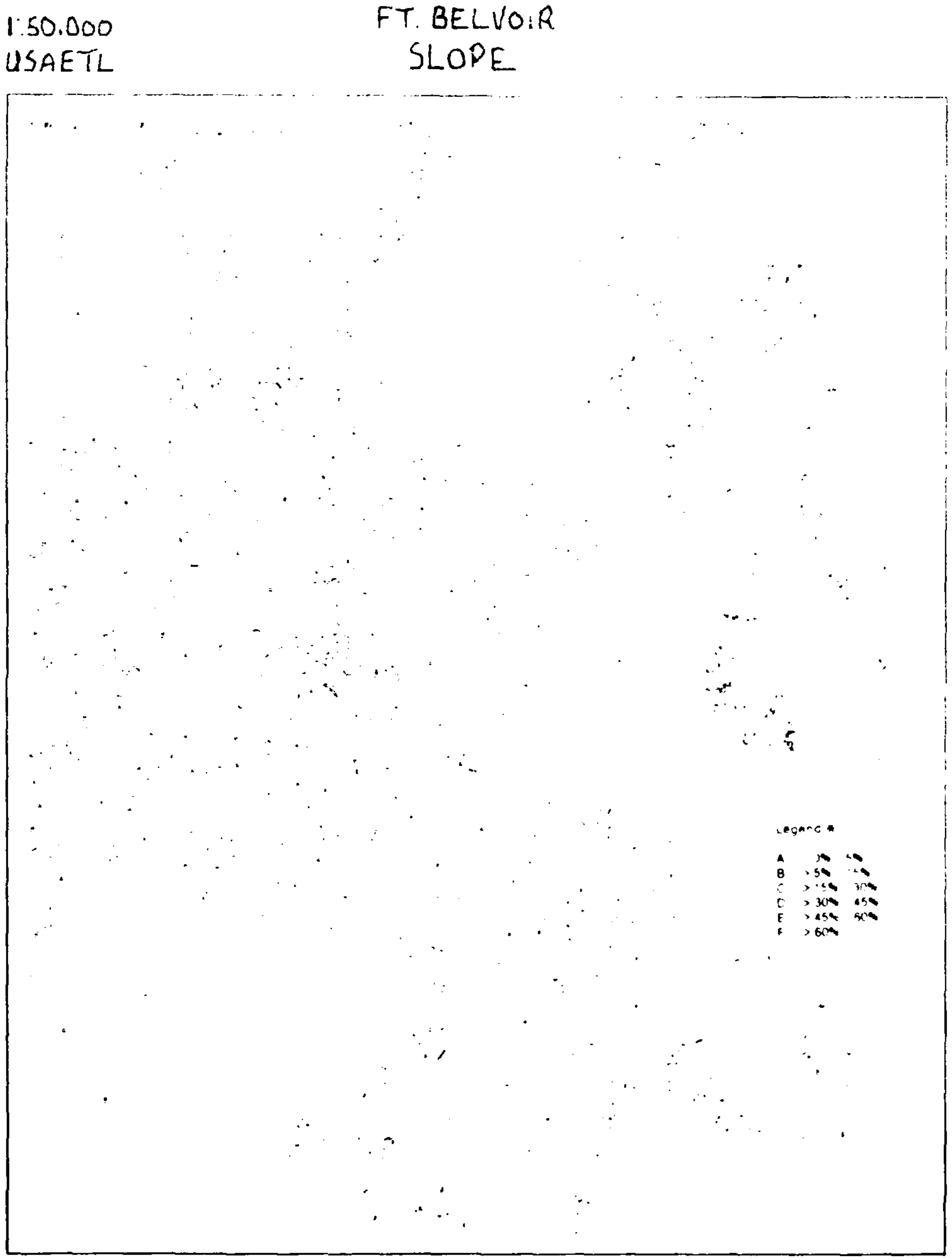
This section describes the detailed procedures the analyst uses to produce a slope factor overlay (figure 4.1). The analyst should read and understand the section entitled "Slope" in FM 21-33, Terrain Analysis, and chapter 6, "Elevation and Relief," in FM 21-26, Map Reading, before proceeding with the materials in this section of the guide. The slope overlay is produced on a mylar overlay registered to a standard military 1:50,000 scale map. Other locally standard maps of differing scale for military operations may be used but will require adjustment to the 1:50,000 scale. Larger scale maps with greater detail may be preferred for landform and surface roughness analysis but the resultant overlay must be reduced to the 1:50,000 scale. The methods for using aerial imagery for slope determination are noted but not detailed in this procedural guide.

4.1 General.

Slope is the inclined surface of a hill, mountain, or any other part of the earth's surface. Slope is usually expressed in one of three different ways as (1) a ratio, (2) angle of slope in degrees, or (3) percent slope. Figure 4.2 illustrates how the three types of slope expression are calculated. The slope as a ratio (gradient) is derived from the relationship between the horizontal and vertical distance expressed as a fraction with a numerator of one. Slope in degrees is the angular difference the inclined surface makes with the horizontal plane. The tangent of the slope angle is determined by dividing the vertical distance, or vertical difference, (VD) by the horizontal distance (HD) between the highest and lowest elevations of the inclined surface under consideration. The result of this calculation is the tangent of the slope angle. The actual angle is then found through the use of trigonometric tables. The third way of expressing the slope is as a percentage. The identification of slope on a terrain factor overlay is expressed as a percentage, which is calculated as the number of meters of elevation (VD) per 100 meters of horizontal distance. In the event that slope information is available to the analyst in degrees or as a ratio for the area of interest, either value may be converted to percent slope through use of a slope conversion scale (figure 4.3).

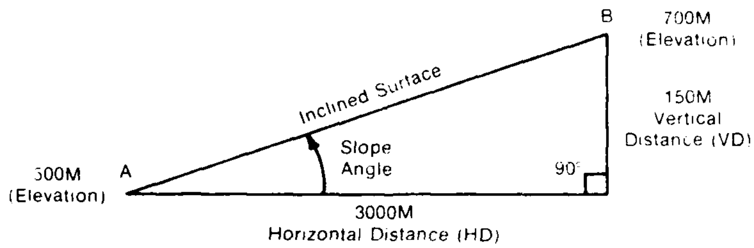
One of the most important synthesized special topographic products for the commander in the field is the cross-country movement (CCM) product. In evaluating terrain for trafficability, a slope of 45 percent is commonly used as the reasonable upper limit for tanks and about 30 percent for military trucks. Six major slope categories are delineated (0-3%, 3-10%, 10-30%, 30-45%, 45-60%, and >60%) to provide the necessary slope data input for the CCM product. These categories represent critical values for the movement of foot troops and vehicles.* The primary slope

*See ETL-0220, Synthesis Guide for Cross-Country Movement, Feb 1980.



*The ranges for slope categories A, B, and C depicted on this overlay are not the ones recommended for CCM and are shown here for illustration purposes only (see ETL-0220)

Figure 4.1. Slope Factor Overlay.



(1) Slope as a Ratio $= \frac{VD}{HD} = \frac{150}{3{,}000} = \frac{1}{20}$

(2) Slope as an Angle in Degrees (Tangent of Slope ∡) $= \frac{VD}{HD}$

$$= \frac{150}{3{,}000} = .0500$$

The ∡ Whose Tangent is .0500 = 2° 52'

(3) Slope in Percent $= \frac{VD}{HD} \times 100 = \frac{150 \times 100}{3{,}000} = 5\%$

Note: For Clarity, the Above Triangle's Proportions and Dimensions Are Exaggerated

Figure 4.2. Methods of Expressing and Determining Slope.

factor overlay should be compiled to satisfy the slope percentage categories for the CCM. However, the analyst may be instructed through special requests to compile slope overlays of differing percentage categories from those needed for the CCM product.

4.2 Slope Determination from Topographic Maps.

The primary means of determining percent of slope is accomplished through the use of a 1:50,000 or larger scale topographic map of the area. If they are available, the analyst should review the compilation and drafting specifications for hypsographic (relief) features for maps that he might analyze before proceeding with this part of the analysis guide. The analyst should be familiar with standard methods and symbols for the portrayal of relief information, e.g., contour lines, depressions, scarps, crevices, cuts and fills, etc. Also, the analyst should be aware of the fact that maps of differing scale will show contours of the same area at different intervals (figure 4.4). Maps of the same scale and series will

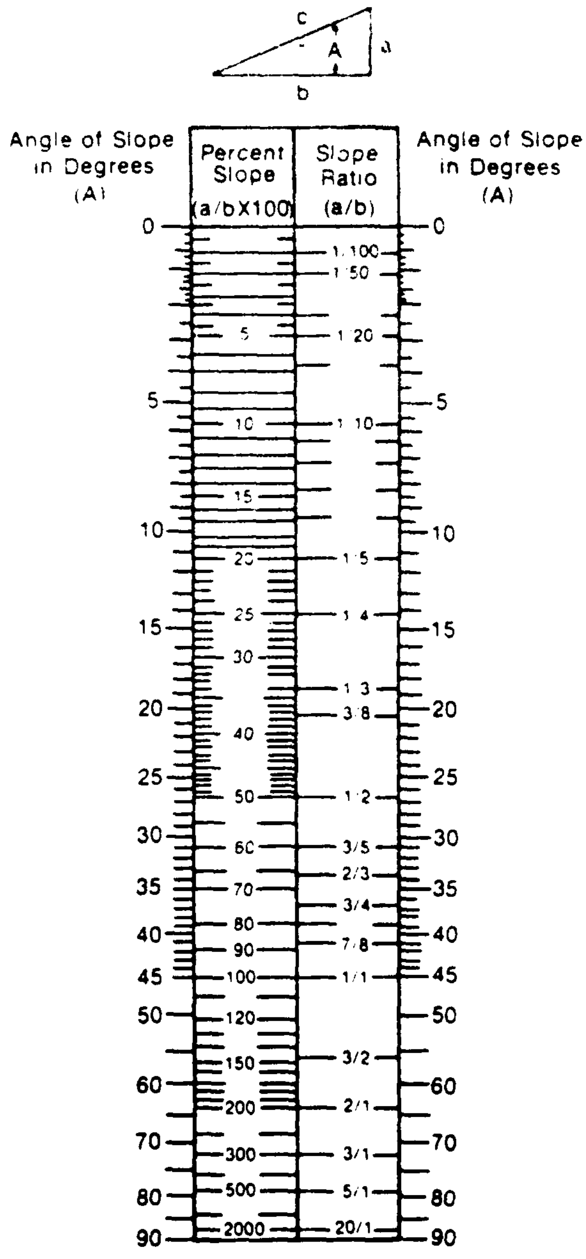
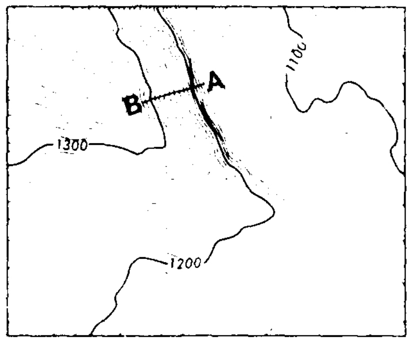
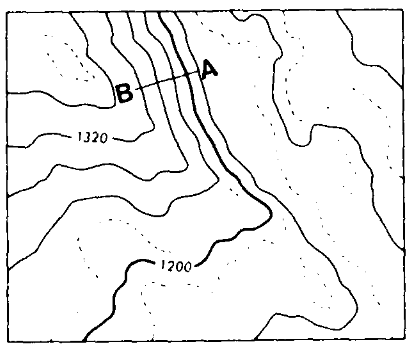


Figure 4.3. Slope Conversion Scale.



CONTOUR INTERVAL = 10M

(Horizontal scale must be known)



CONTOUR INTERVAL = 40M

(Horizontal scale must be known)

Figure 4.4. Different Contour Intervals of Same Area.

not necessarily have the same contour interval, because of extreme elevation differences on some portions of the map sheet.

To obtain the maximum slope in percent for a given area of a map, the measurements are made perpendicular to the contour lines. Figure 4.5 shows a hillside with three lines (AB, CB, and DE) that indicate the maximum slopes in three areas on the face of the hill. For line AB the vertical distance taken from the contour interval between A (at 100 m elevation) and B (a spot elevation of 193 m), is 93 meters. The horizontal distance of line AB at the map scale is 2,600 meters. Therefore:

$$\text{Slope in percent (line AB)} = \frac{VD}{HD} \times 100 = \frac{93 \text{ m}}{2{,}600 \text{ m}} \times 100 = 3.58$$

Using the same measurement and computational procedure, the slope for line CB equals 3.32 percent and for line DE the slope equals 4.44 percent. Standard map-reading procedures are used for obtaining the vertical and

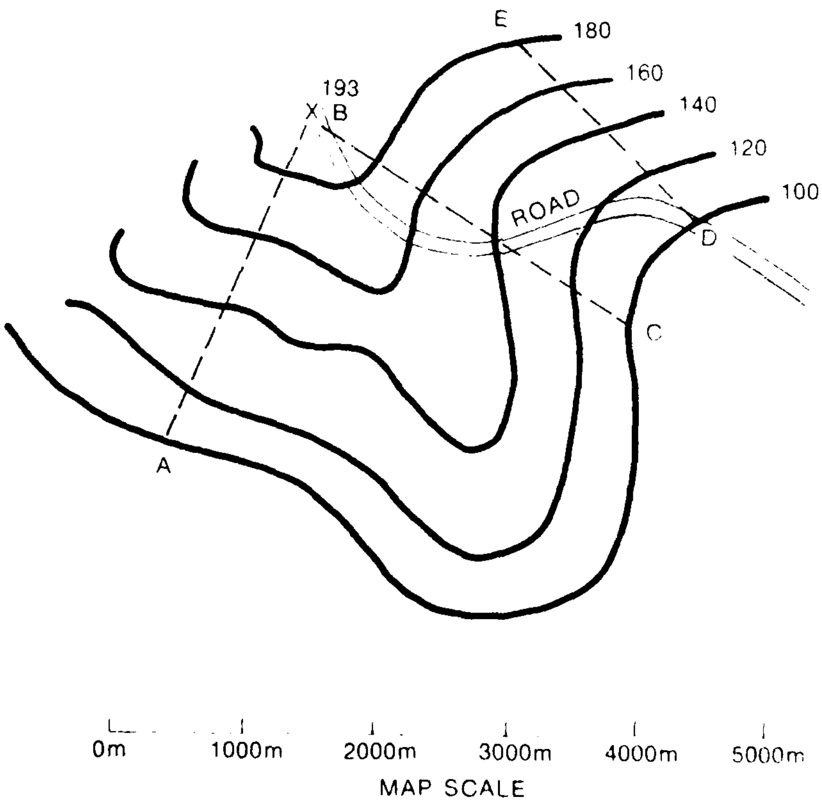


Figure 4.5. Determination of Slope Using Map Measurements

horizontal distances from the source map. Careful attention must be paid to the map scale, contour interval, relief feature symbolization, and the scaling of distances from the source map. Repetitive measurements and mathematical computations are too time-consuming for efficient production of the factor overlay. A more efficient procedure follows.

For practically all slope factor overlay compilations from source maps of known scale and contour interval, the terrain analyst uses a device called a slope calculator.

4.2.1 Slope Calculator. Figure 4.6 shows a simple slope calculator constructed of stiff clear plastic. For purposes of clarity, an explanation of this calculator is provided using a map of 1:20,000 scale and a contour interval of 5 meters. The tick mark spacing on the edge of this calculator

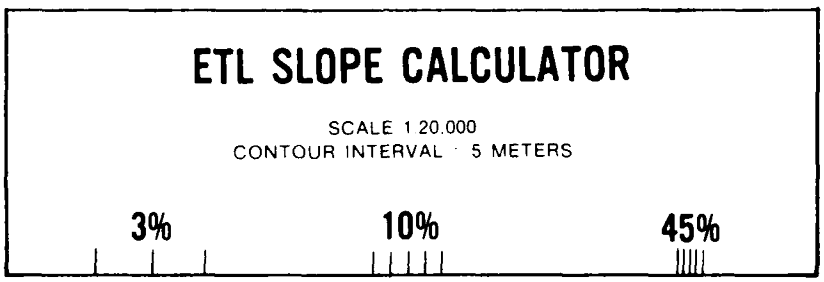


Figure 4.6. Sample Slope Calculator.

(figure 4.6) has been predetermined and plotted to show contour spacing for three of the CCM slope percentage categories. In actual practice, all six CCM slope percentage categories (see section 4.1) would be determined in terms of contour spacing for the example 1:20,000 scale map. However, at the given scale and contour interval, the spacing of contours for 60 percent or greater slopes would be too closely spaced for measurement.

Other slope calculators can be made for different map scales and contour intervals by using the percent slope formula in reverse and by correcting for the map scale. Figure 4.7 illustrates a universal slope calculator that shows contour spacing for commonly extracted percentages of slope for a number of maps of varying scale and contour interval. The

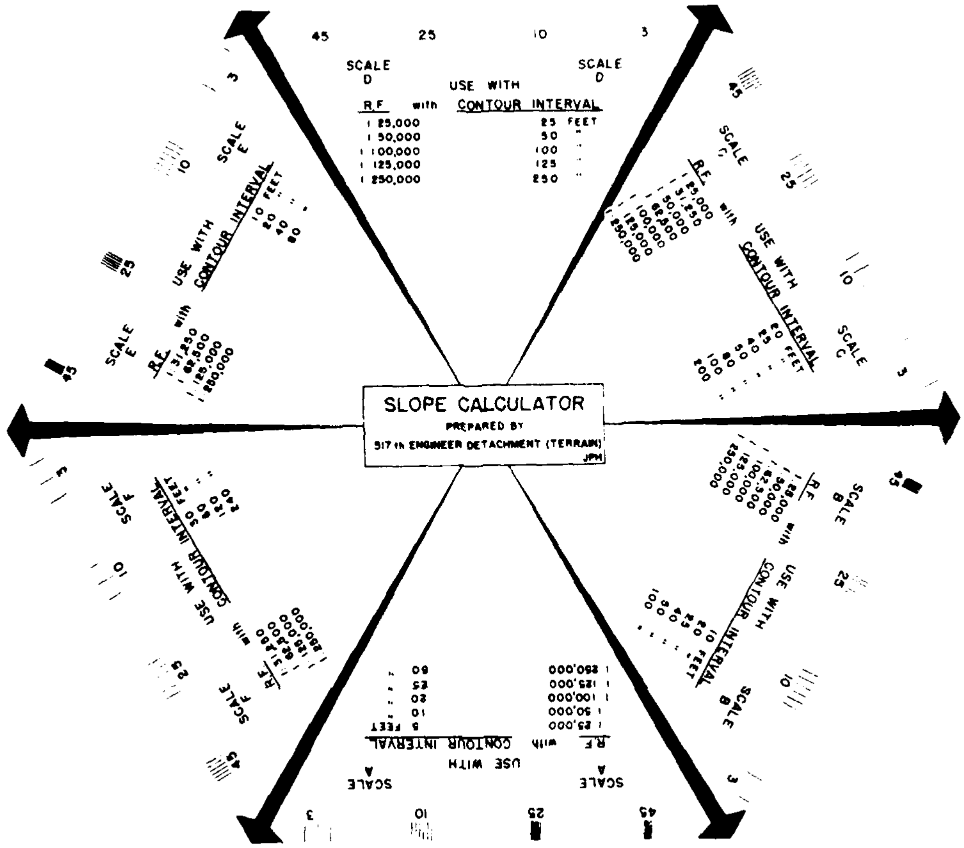


Figure 4.7. Sample Universal Slope Calculator.

general equation for determining contour spacing at various slope percentages on maps of differing scale is as follows:

$$\text{Contour line spacing} = \frac{100}{\%\ \text{slope}} \times \text{contour interval (CI)} \times \text{map scale}$$

representative fraction (RF).

Examples of the determination of contour line spacing for specific slope percentages follow:

Example 1 - Find the contour line or slope calculator line spacing that represents a slope of 30 percent on a 1:24,000 scale map that has a contour interval of 10 feet.

$$\frac{100}{\%\ \text{slope}} \times CI \times RF = \frac{100}{30} \times 10\ \text{ft} \times \frac{1}{24{,}000} = 0.00139\ \text{ft} = 0.017\ \text{in.}$$

Example 2 - Find the contour line or slope calculator line spacing that represents a slope of 3 percent on a 1:20,000 scale map that has a contour interval of 5 meters.

$$\frac{100}{\%\ \text{slope}} \times CI \times RF = \frac{100}{3} \times 5\text{m} \times \frac{1}{20{,}000} = \frac{500}{60{,}000} = .00833\text{m} = 8.33\ \text{mm}$$

Note that the result from example 2 applies in the construction of the slope calculator shown in figure 4.6. On this sample slope calculator, the distance between the edge ticks that represent the 5-meter contour spacing for 3 percent slope areas is actually 8.33 mm. The analyst may wish to compute a table of contour line or tick spacings for commonly used source maps of varying contour intervals. Also, this table should account for variations in the slope percentage extraction requirements. Table 4.1 shows the results of this type of computation for maps of 1:50,000 scale that show varying contour intervals in both feet and meters. Data from this table could be used to construct a variety of slope calculators for the 1:50,000 scale map.

From the foregoing slope calculator computations, it becomes rather obvious that, for some map scales with given contour intervals, the contour spacings on the calculators can become very closely spaced at the higher slope percentages. When this occurs, drafting of the calculator under magnification is required. Another solution is to draft the calculator at a larger scale and then to photographically reduce the calculator to the required map scale. Also, the calculators can be made easier to use by deleting alternate lines or by doubling the contour interval of the calculator.

After the analyst has constructed a slope calculator as shown in figure 4.6, or after he has selected an appropriate existing calculator from his files, the extraction of slope percentages from the base map becomes a simple but tedious manual task. As you recall, the calculator in figure 4.6 can be used only with a map of 1:20,000 scale with a contour interval of 5 meters. Figure 4.8 shows three cross sections labeled 1, 2, and 3 drawn across a portion of a topographic map of Puerto Rico. The source map is 1:20,000 scale, and the contour interval is 5 meters. Moving the slope calculator along section 1, a good match is made between the maps contours and the etched 10 percent slope lines on the calculator (figure 4.9). Turning to figure 4.10, the calculator is laid along section 2. The map contour lines here match the group of etched calculator lines labeled 3 percent. The last match is made along section 3

Table 4.1. Slope Calculator Construction Information for a 1:50.000 Scale Map.

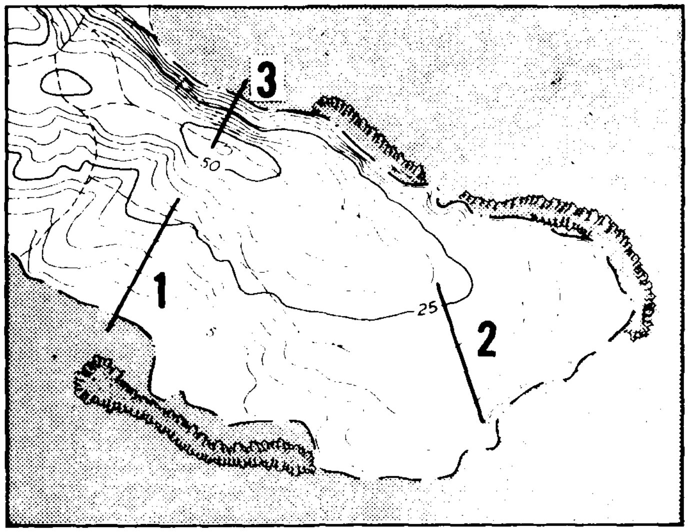
SLOPE CALCULATOR TICK SPACING FOR 1 50.000 SCALE MAP

TICK SPACING IN INCHES

SLOPE	10 FEET	20 FEET	40 FEET	50 FEET
3%	080	160	319	399
8%	029	060	119	149
10%	024	048	.095	119
15%	015	032	063	079
30%	007	015	031	039
45%	005	010	021	026
60%	003	007	015	019

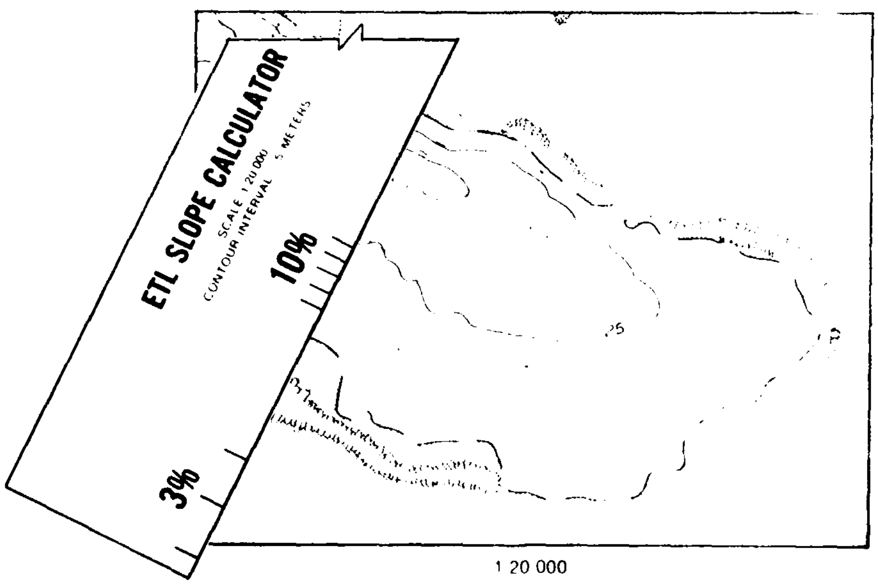
SLOPE	5 METERS	10 METERS	20 METERS	25 METERS	30 METERS	40 METERS	50 METERS	100 METERS
3%	131	262	524	656	787	1 049	1 312	2 624
8%	049	098	196	246	295	393	492	984
10%	039	078	157	196	236	314	393	787
15%	026	052	104	131	157	209	262	524
30%	.013	026	052	065	078	104	131	262
45%	008	017	034	043	052	069	087	174
60%	[illegible]	013	026	032	039	.052	065	131

Calculator Drafting Specifications
003" lineweight
Each tick 300" long



1:20,000
CONTOUR INTERVAL = 5 METERS

Figure 4.8. Several Cross Sections to Be Measured for Slope.



1 20 000
CONTOUR INTERVAL 5 METERS

Figure 4.9. Matching the Calculator's 10% Slope Tick Marks With the Contour Lines on Section 1.

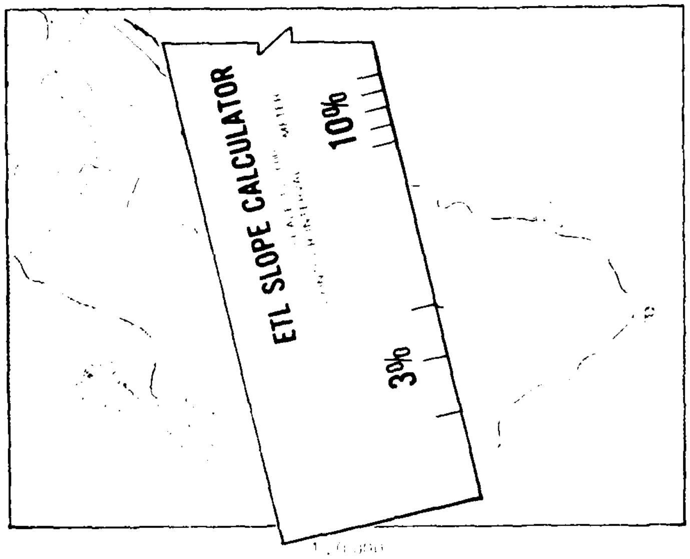


Figure 4.10. Matching the Calculator's 3% Slope Tick Marks With the Contour Lines on Section 2.

and the slope is found to be about 45 percent (figure 4.11). A simplified, partially completed version of the final slope overlay appears in figure 4.12. The analyst may elect to code the factor overlay with numbers or alphabetic characters, e.g., 1 = 0-3%, 2 = 3-10%, etc.

4.2.2 Slope Factor Overlay Preparation.

a. Prepare the mylar overlay in the format described in Appendix A.

b. Starting in the upper left hand corner of the map sheet, use the slope calculator to determine the slope classes and delineate the boundaries where changes occur, as in figure 4.12.

c. Write the slope class percentage or code in each area and progress across and down the map sheet until all areas are completed.

d. Ignore any areas with greatest dimension less than 2 mm, unless the slope is greater than 60 percent or the map symbol for escarpments is shown. In those cases mark the areas with the symbol for escarpments.

e. Check the draft overlay for completeness and ink the final line work and symbols.

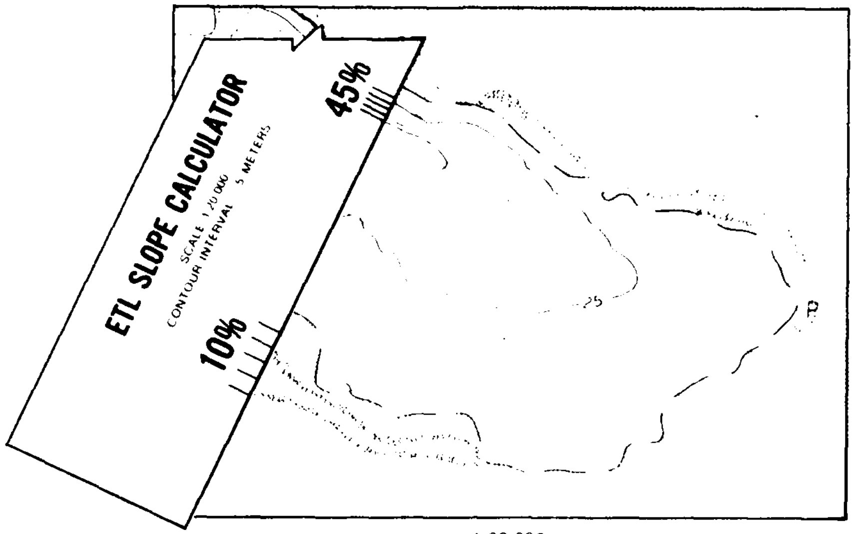


Figure 4.11. Matching the Calculator's 45% Slope Tick Marks With the Contour Lines on Section 3.

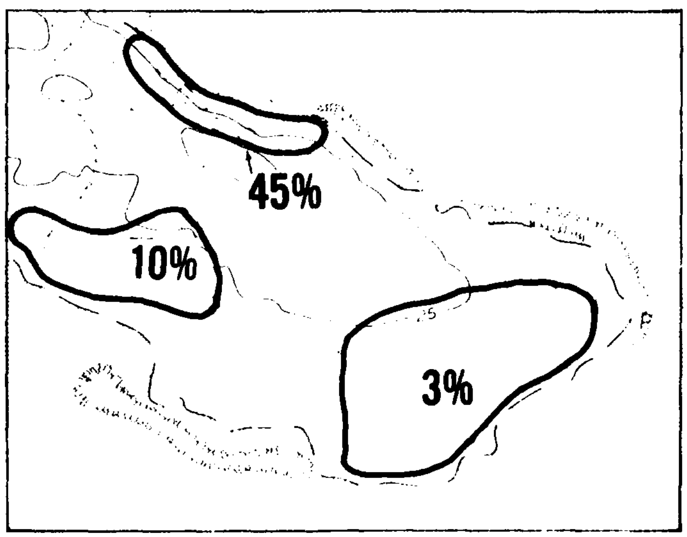


Figure 4.12. An Example of Several Areas Where Slope Has Been Calculated Using the Slope Calcuiator.

4.3 Slope Determination from Airphotos.

Slope determination using aerial imagery requires complete stereo coverage of the area of interest. It is more time consuming and requires more skill than using the topographic map. Slope determination using 1/50,000 scale airphotos provides little or no gain in accuracy over that attainable using a 1:50,000 topographic map. However, the photo method of determining slope may be useful in case no maps are available and the stereo coverage is. The analysis consists of examining the study area landforms one at a time. Typical locations within a landform are given a slope class based on measurements averaged over a portion of the landform; three or four of these will provide a reasonable average. The following procedure is suggested:

With the parallax wedge or height finder, a parallax value is determined between two points to determine the vertical distance. The horizontal distance between the same two points is then measured. To calculate the slope use the relationship

$$\text{Slope } (\%) = \frac{\text{Vertical distance}}{\text{Horizontal distance}} \times (100).$$

Each landform is measured and a slope class determined as stated above.

5. LANDFORM ANALYSIS METHODS

This section provides instructions for conducting a landform analysis and for compiling a landform factor overlay through the use of literature, topographic maps, and aerial/LANDSAT imagery. Use of literature, maps, and imagery is very important, as each source provides a unique contribution to the overall landform analysis. It is strongly suggested that the terrain analyst use all three sources in an integrated approach to the process of landform identification and delineation. Though it is suggested that an overlay be constructed for each type of source material, in actual practice it may be unnecessary for three overlays to be produced. At a minimum, the airphoto landform overlay must be produced, and during this process the topographic map and LANDSAT imagery can provide additional information to aid in the delineation and identification of the landforms. For the overlay, the terrain analyst integrates all three sources of information into one factor overlay combining all his observations.

The analysis methods presented in this section are illustrated by an example landform study of the Fort Belvoir, Virginia area (section 5.4). Similar steps and source materials would be used in a landform analysis for any area in the world. To supplement the basic landform analysis procedures outlined in this section, the analyst should consult the list of references and publications found in the Bibliography.

5.1 Data Base Preparation and Analysis.

Background information that aids in characterizing the landforms and surface conditions should be maintained in a data base for a given region. The data base is developed from the general to the specific as the terrain analyst consults maps, literature, and other sources for information. This information aids in the preliminary identification of the landforms of a given study area. Often this step is known as the regional analysis phase.

To provide a data base, descriptive data are extracted from several sources. The topics/sources include geography, climate, physical features and landforms, bedrock and surface geology, general soils, hydrology and drainage, vegetation and land use, LANDSAT imagery, and airphoto indexes. Stereo photos and topographic maps are studied in the detailed analysis phase after formation of the data base. The topic/source description and material suppliers are shown in table 5.1. Essential sources for the data base are literature and small-scale thematic and topographic maps.

5.1.1 Literature Analysis. This portion of the landform analysis procedure is accomplished prior to the analysis of maps and imagery. It involves reviewing the data files and selecting and evaluating the available source materials. This process enables the analyst to define information gaps and develop collection requirements to supplement

Table 5.1 Data Base Compilation.

Summary	Sources	Objective of Data Base
The Sources provide background information on landforms geology soils bedrock and geographic environmental conditions etc to compile the DATA BASE	*Landsat Maps Photos are consulted for regional local data related to given surface configuration*	*To characterize landforms geology bedrock soils environmental conditions relative to surface configuration*

Supplier	Topic Source	Description	Content
Hammond Inc 515 Valley Street Maplewood NJ 07040 (201) 763-6000 (0-8437) and US Geological Survey (USGS)	Geography	Map General - 1 500 000 scale State Federal - 1 250 000 scale USGS Sheets	Geographic locations and general topography roads railroads streams elevations and other data
U S Weather Bureau NOAA County Soil Survey Reports	Climate	*Weather Records*	Seasonal distribution of high low temperatures average rainfall first and last frost dates number of crop-growing days
Ginn & Co A Xerox Publishing Co 191 Spring Street Lexington MA 02173 (617) 861-1670 (0-663)	Physical Features and Landforms	Physiographic Diagram Landforms of the country Landform distribution map 1 1 000 000 or smaller scale	General distribution of landforms, diagram of physical divisions and features types of landforms to expect
U S Geological Survey State or Federal Agency (see below)	Bedrock and Surface Geology	Map bedrock formations - 1 500 000 or larger scale	Bedrock structure and general or areal distribution of surface formations
U S Dept of Agriculture (USDA) Agriculture Stabilization & Conservation Service (ASCS)	General Soils	Map general distribution of soils classes 1 500 000 or larger scale	General surface soil distribution and classification
State Dept of Natural Resources	Hydrology and Drainage	Map principal streams and tributaries - 1 500 000 or larger scale	General distribution of streams and watershed areas
State Dept of Natural Resources U S D A A S C S Soil Survey Reports	Vegetation and Land Use	Map general vegetation cover - 1 500 000 or larger scale Map general classes of land use and their distribution 1 500 000 or larger scale	Distribution of vegetation by species or major groups Distribution of land use with Level I or higher classification
EROS Data Center Sioux Falls SD	LANDSAT Imagery	Satellite image 1 250 000 scale Bands 5 and 7	General geological landform hydrological and land use features
USDA Salt Lake City Utah	Airphoto Index	Index sheets Airphoto Mosaic of given county 1 62 500 or larger scale	Flightline photo print numbers date of photography also landforms roads drainage geological and soil patterns on countywide basis
		DETAILED ANALAYSIS PHASE	
USDA Salt Lake City Utah US Forest Service	Stereo Airphotos	Stereoscopic coverage 1 20 000 or smaller scale	Identification Symbols Roll No Print No photo pattern data element information
U S Geological Survey 1200 South Eads Street Arlington VA 22202 and/or Defense Mapping Agency Hydrographic Topographic Center (DMAHTC) Washington D C	Topographic Maps	Military Series Quad sheets 1 24 000 to 1 50 000 or smaller scale	Elevation data natural and cultural features vegetative cover drainage roads RR etc

available materials. Following acquisition of the study materials, each source is carefully studied relative to the given terrain and in the order shown in table 5.1. This background information establishes the data base. Copies of all types of source materials are provided in appendix B for the landform study example.

5.1.2 Topographic Map Analysis. The topographic map is a basic source of information that is integrated with the data base. The types of information generally extracted from a topographic map are defined as follows:

a. County/State/Country - This information is easily found on a topographic map; an example is used to assist with the definitions (figure 5.1). State or country is normally listed on the title block in the top or bottom righthand corner. In the United States, county names are recorded along county boundary lines. Note the boundary line on figure 5.1 between Hart County and Barren County, Kentucky near the map center. For areas other than the United States, the analyst notes the name of the country, territory, or political division.

b. USGS Quadrangle or U.S. Army Topographic Series - The topographic map identity is located in the top righthand corner of the example (see figure 5.1), Horse Cave Quadrangle, Kentucky, 7.5 Minute Series.

c. Land Use - Knowledge of the land use features of the landform is useful. Typical land uses are shown on the topographic map; for instance, forested areas, sand and gravel quarries, orchards, and swamps are represented by symbols. The rather uniform, spread-out contour spacing can provide some insight as to the possibility of agriculture; for example, cultivation given sufficient rainfall is highly likely on flat land (represented by open-spaced contour lines). As in the case of a limestone plain, which is relatively flat, there is often a predominance of agriculture along with other features such as woodlots and quarries. Of course, if there is residential or urban development, it will be easily recognized from the map symbols. For an illustration of the land uses for a limestone plain, see figure 5.1.

d. Special Features - The recognition of a certain feature peculiar to a given landform can uniquely separate it from all other landforms; for example, an arc-shaped feature indicates an alluvial fan landform, a snake-like ridge is characteristic of an esker, and the circular depressions or sinkholes of karst topography are common only to limestone formations.

e. Form - Form simply refers to the arrangement as a geometric form; how the landform presents itself on a topographic map. The form may be identified as curvilinear, rectangular, circular, linear, oval, etc. If the landform has no definite geometric form, it is labeled

Horse Cave Quadrangle
Kentucky
7.5 Minute Series (Topographic)

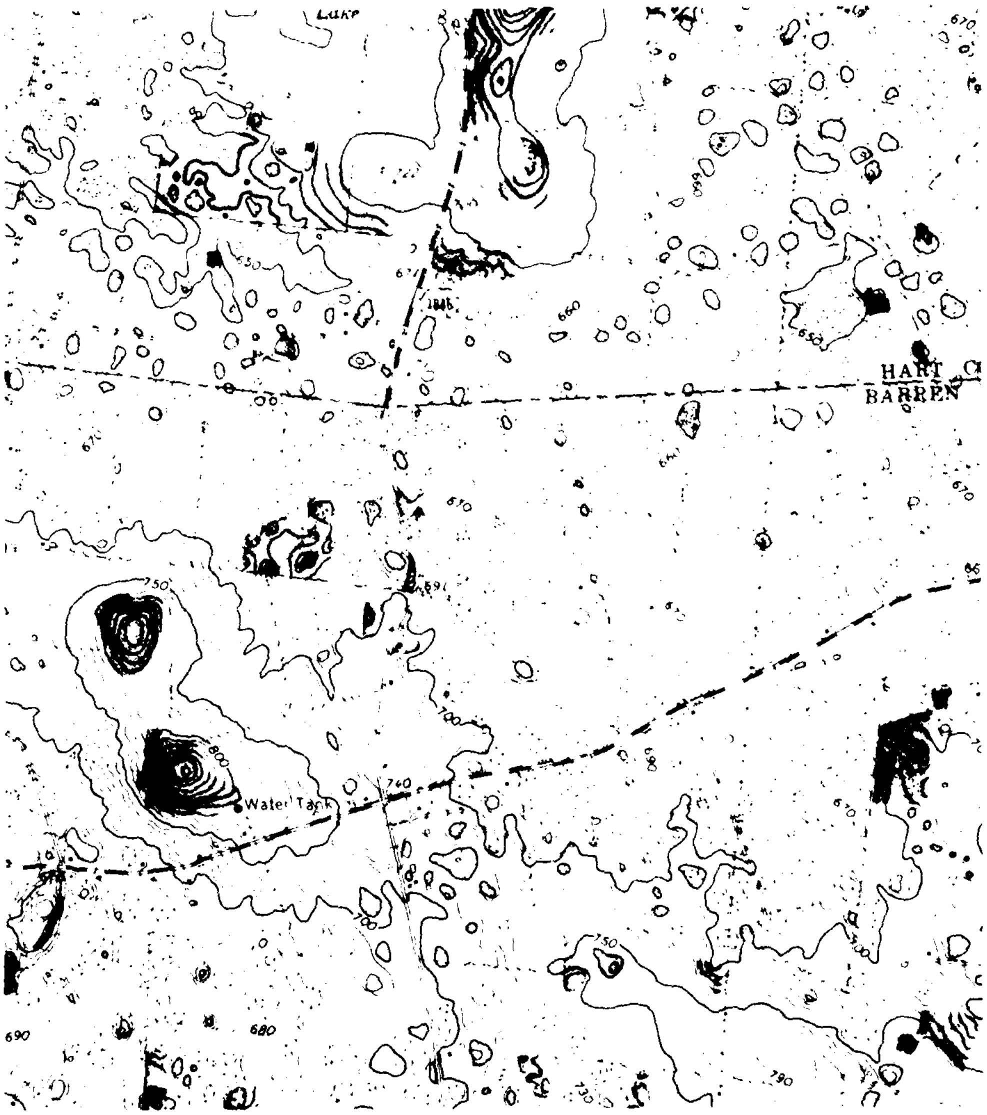


Figure 5.1. Illustration of a Topographic Map. Horse Cave, KY.

irregular or indeterminate. The form of this limestone plain is not definite, because of its highly-varied topography (e.g., [illegible] and haystacks). Therefore, it is denoted as irregular or indeterminate.

f. Texture - In this discussion, texture concerns the spacing and arrangement of contour lines; these indicate the roughness or smoothness of the landform surface. Texture is designated as fine, medium, or dense. A limestone plain is relatively flat and smooth, a condition depicted by the regular and uniformly-spaced contour lines. The texture for a limestone plain is designated as medium.

g. Slope and Elevation - The topographic map provides information on the slope and elevation of landforms. It also serves as a back-up source of information to confirm or enhance observations made during the airphoto analysis, especially the correlation of a given landform with the appropriate elevation data.

5.1.3 Airphoto, Photo Index, and LANDSAT Images. Boundary lines are marked on the factor overlay where tonal and topographic changes occur. These changes often occur at slope breaks, where the one landform surface interfaces with another. These topo/tonal breaks enable the analyst to visualize boundary lines for separating the landforms. While observing stereoscopically the relief-change locations, the analyst will note contrasting light to dark tones that represent changes in vegetative cover. It is useful to observe the mosaic and topographic maps alternately for these tonal/topo markings.

Tonal conditions should be noted on the photo index while marking boundaries to separate landforms. Flat, generally level, or low relief terrain is characterized by dark tones. The irregular surfaces of both wooded and urban terrain assist in the search for landform boundaries. The irregular-relief indicates an elevated landscape. Dark-light tones, and slope-break tone contrasts are indicative of relief differences in the predominant features.

Other aids to the landform delineation are LANDSAT images. Both band-five (red reflectance) and band-seven (near infrared relfectance) images are valuable. The analyst should study the black-and-white tonal changes on band-seven images to aid in the delineation of landform boundaries. Tonal differences can be used to partition the terrain types; and changes in the black-and-white tone-texture distinguish the drainage system and variations in vegetative cover. On the band-seven scenes, the analyst can look for dark, irregular tones that indicate urban, built-up areas (e.g., streets and buildings). Lowland and wetland areas are observed as dark-toned to black. Low grassland cover is distinguished from intermittent water surfaces by light tones versus the black tones of water. Lakes and water in open drainage ways are easily separated from low, flat areas by the dark-toned areas; water is dark to black, whereas the vegetated low areas are bright to very light-toned.

On band-five scenes, power line corridors and built-up areas are indicated by light-gray tones; these will vary from bright to dull gray. Forest cover appears dark gray, while water surfaces vary from light dull-gray to nearly black. Marshlands are dark or dull-gray toned because of the grass-cover, but the dark to dull-gray tones indicate water surfaces. Intermediate to level surfaces are light- to dark-toned with built-up areas having light tones; the forest-covered areas are dark. Flat grasslands exhibit tones that are generally dull- to light-gray.

LANDSAT false color images are also useful. The colors of red, light green, to tan or beige, and blue to light blue reveal variations in land cover. Vegetative surfaces are recorded in red hues, indicating live green vegetation. The light green-gray to tan or beige colors indicate built-up areas. The blue to light blue (low reflectance) areas identify wet or water-covered terrain.

5.2 Photo Pattern Data Elements and Analysis.

Analysis of information in the data base results in characterization of the origin and development of landforms the analyst expects to encounter during the airphoto interpretation. This background information forms the basis for developing photo pattern data element descriptions for each landform. These elements include form or topographic position, drainage system, gully characteristics, special features, color (photo-gray tones), land use, and vegetation. The analyst records observations about each of the elements in a format similar to table 5.2.

The procedure for photo identification of landforms can be generally broken down into three alternative methods:

1. Photo pattern data element descriptor matching

2. Hypothesis and descriptor matching analysis

3. Recognition of landform identity based on experience

In the first method the analyst observes the landforms on the airphotos and prepares a set of photo pattern data element descriptions for the unknown landforms as outlined above. The analyst then compares the set of descriptors with those given for typical topographic geologic forms in section 7. The analyst is not limited to only those landforms contained in section 7; rather, additional reference information should also be used in the landform identification process. Once the descriptors of the unknown landform are matched with similar descriptors of a landform of known identity, the landform is identified. A variation of this method requires the analyst to hypothesize the identity of the unknown landform based on the landform's set of descriptors. This initial hypothesis is then accepted or rejected based on the level of agreement between the reference set of descriptors and analyst's observed set.

Table 5.2 Form for Recording Photo Pattern Data Elements

PHOTO PATTERN DATA ELEMENTS Photos Physiography	
ELEMENTS	[illegible]
Form	
Drainage	
Gully Characteristics	
Special Features	
Color (Photo Gray Tones)	
Land Use	
Vegetation	

In the second method the analyst, generally a more experienced one, applies hypothesis testing in a different manner. Using this method, the analyst first hypothesizes the identity of the landform; for example, glacial outwash plain, based on background information and experience. With this hypothesis in mind, the analyst (photointerpreter) then asks himself questions based on the common set of seven landform descriptors; e.g., if it is a glacial outwash plain, its form should be a flat to undulating plain - does it have this form? The analyst mentally answers this question, referring to the airphotos as necessary to confirm his answer. Also, if it is a glacial outwash plain its drainage system is internal - is this true of the unknown landform? The analyst continues this "if - then" questioning, referring to the airphotos as necessary, until all seven photo pattern data element descriptors have been examined and evaluated. If five or more of the reference set of descriptors match the unknown landform's physical expression, then the landform's

identity matches the hypothesis. On the other hand, if a majority of the descriptor questions generate negative responses, then the hypothesis is rejected and another landform identity hypothesis is tested. This procedure is continued until the correct typothesis is made.

The third method, the experienced analyst's approach, requires recognition of the landform's identity because the analyst has observed the same or a similar landform pattern on the ground or on airphotos previously.

The photo pattern data elements used in the landform identification process are described in the following paragraphs.

5.2.1 Form, Topographic Position. Topographic position is the expression of physical relief of the land surface as developed by erosional or depositional processes under given climatic and geologic conditions. The topographic position of landforms is described in terms of shape, relief, and slope. Taken together, descriptions of these features can provide valuable clues as to the identity of an unknown landform. For example, each landform of glacial origin, such as moraine, drumlin, kame, esker, and lakebed has a characteristic shape, relief, and slope. Each glacial landform is therefore identifiable as a singular feature by stereoscopic observation, and often is uniquely characterized by the combined descriptions of shape, relief, and slope. The description of form includes a general statement about the topography such as "plain, level, gently sloping to sea"; this information is recorded on a form, such as table 5.2.

5.2.2 Drainage System. There are numerous drainage patterns, and the plan views of some are presented in figure 5.2. Six patterns are basic, and they include dendritic, trellis, radial (centrifugal), parallel, annular, and rectangular. These basic types are described below.

Dentritic patterns are generally associated with landforms composed of flat-lying rocks and impervious soils. Folded, tilted, and faulted rocks often create landforms that are identified from a trellis drainage pattern. Cones, peaks, and domes of igneous materials create centrifugal (radial) drainage patterns. Gently sloping landforms such as eolian plains are associated with a parallel pattern. Annular patterns are associated with domes of layered rock with variable resistance to weathering. Landforms with rock joints or angular changes in rock materials are associated with a rectangular drainage pattern.

The regional characteristics of terrain surfaces are often indicated by the drainage pattern. The drainage pattern may provide a clue

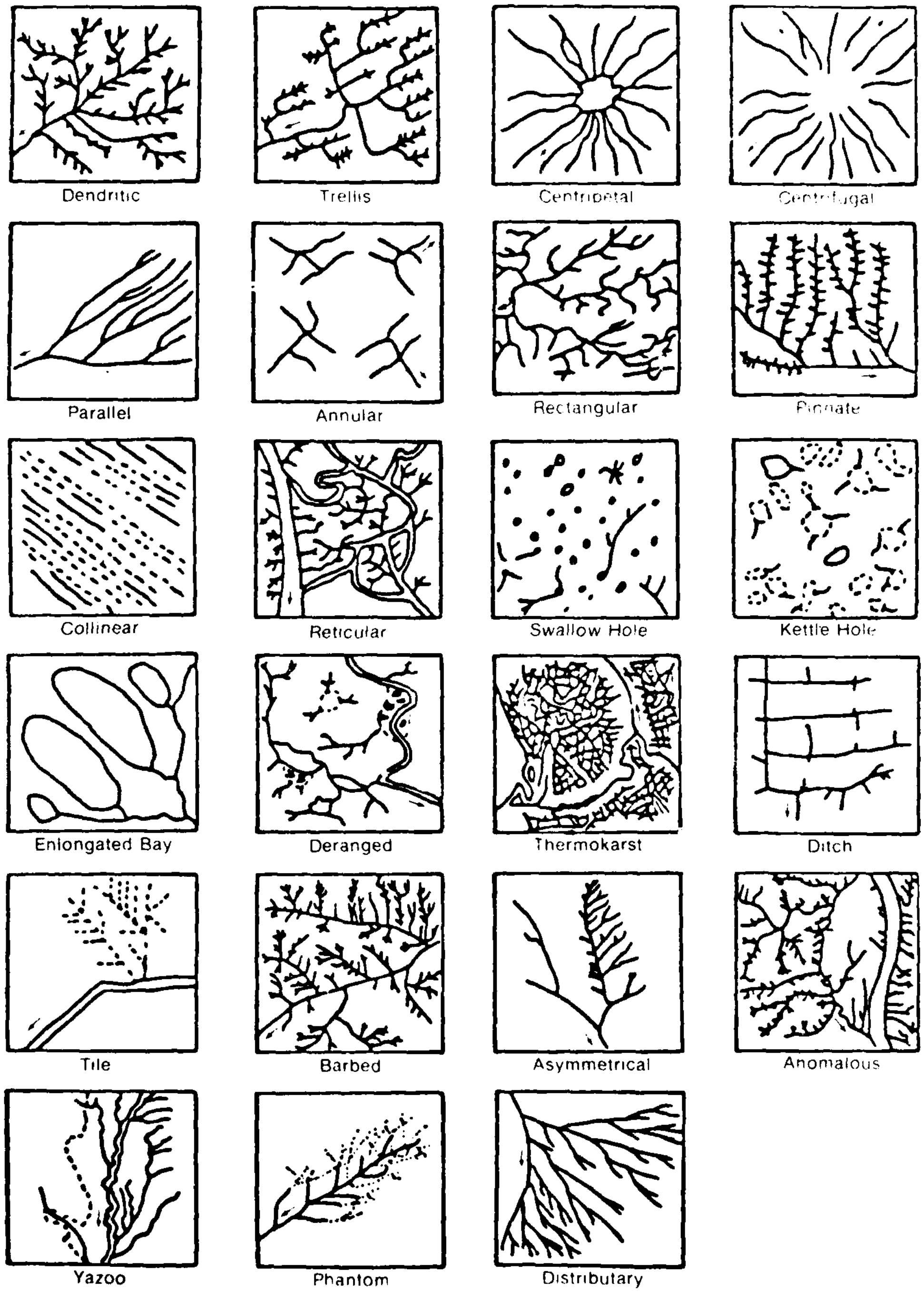


Figure 5.2. Typical Drainage System Patterns (After Parvis).

concerning dip, strike, or type of bedrock and the general depth of the surface materials. The type of surface material is reflected in the landform drainage system. For example, the complete absence of surface drainage indicates pervious materials such as sand. A highly integrated system with branching tributaries indicates an impervious soil with poor internal drainage, such as clay or silt.

To perform a drainage analysis, the drainage ways or the runoff of watersheds are viewed stereoscopically and delineated on a map or overlay. The collective drainage ways form a pattern, which is associated with a given topographic/geologic formation. An example of a statement describing the drainage pattern is, "dendritic with meandering streams." Record the drainage characteristics in a photo pattern data element table for each landform.

5.2.3 Gully Characteristics. Gully characteristics and/or erosional features observed in the study area can be used to infer surface materials and soil profiles. This inferred information can be used to identify an unknown landform. Natural features such as forests, however, can obscure gully characteristics, such as cross section and profile, and thereby reduce the usefulness of this landform indicator. Also, climatic conditions can complicate the interpretation of the erosional features; therefore, the analyst will rarely use the erosional features alone to predict the identity of the landforms. For this reason, the collective photo pattern data elements are needed for identifying landforms.

There are four general cross-section classes for gullies. Each class is associated with a certain surface material and profile (figure 5.3). V-Shaped gullies with short, steep gradients are associated with granular materials such as found in glacial outwash terraces. Loessial landforms have a U-shaped cross section near the headward portions of gullies. Coastal Plain landforms have sand/clay erosional features with flat-bottomed gullies; sharp, steep side-slopes; and low, flat gradients. Cohesive soils have softly rounded, saucer-shaped gullies with long gradients that often indicate shale uplands. There is no specific gully classification for landforms consisting of layered soils with strong profiles. The analyst should be aware that the gully cross section and profile characteristics can be misleading. An example is a gully within or near the boundary of a terrace or a valley wall, where cross section and profile exceptions do occur.

The gully characteristics are described in general terms such as "broad U-shaped or V-shaped with steep gradients." As the gully characteristics are observed stereoscopically, the information is recorded on a photo pattern data element table for each unknown landform.

5.2.4 Special Features. There are certain features that are uniquely associated with specific landform/surface conditions, and these can aid

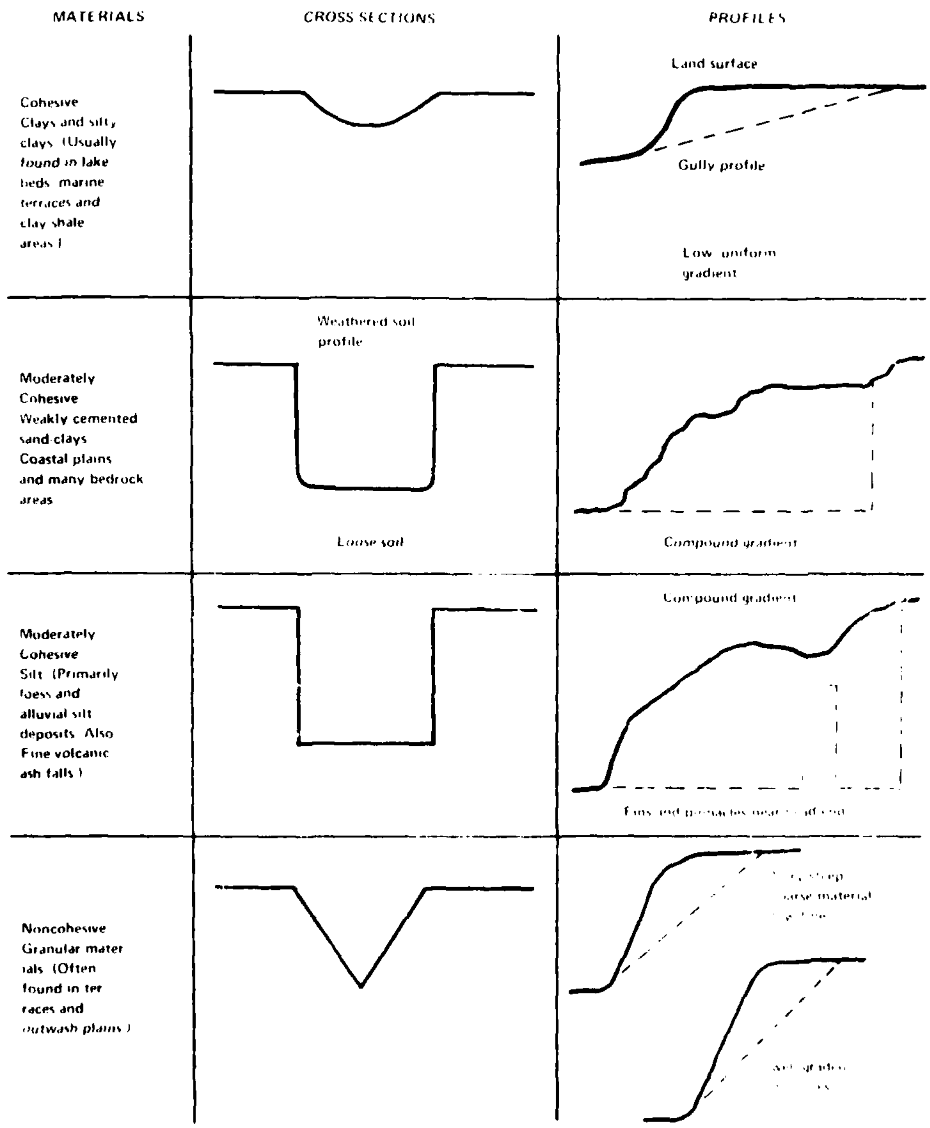


Figure 5.3. Gully Characteristics, Cross Sections, Profiles and Associated Soils

Source: Way, D.S. Terrain Analysis, 1978, © Dowden, Hutchinson & Ross, Inc. Stroudsburg, PA, p. 53

in the landform identification process. For example, vertical-sloped features, such as catsteps, pinnacles, and terracettes, are associated with loessial plains. A pinnate drainage system with U-shaped gullies is associated with loessial upland plains. Sinkholes, haystacks, and other karst features indicate landforms underlain by soluble limestone bedrock. Mottled gray tones and white-fringed gullies on photos indicate young and old till plain landforms respectively. Stream flow scars, natural levees, and cutoff channels indicate alluvial plain landforms. In arctic and subartic regions, landforms with polygonal patterns indicate soft silts and expansive clays.

Special features should be examined stereoscopically, as they may be unique to the landform. For example, "parallel ridges alternating with troughs" are characteristic of beach ridge landforms. Record this special feature information in a photo pattern data element table for each unknown landform.

5.2.5 Color (Photo Gray Tones). The gray tones depicted on panchromatic air photos are the result of surface spectral reflectance variations. These variations result from terrain factors including soil color and texture, vegetative cover, soil moisture, and slope/aspect. Every landform has an observable distribution of gray tones, which is a manifestation of the surface conditions on the landform. A given distribution of gray tones may or may not be a definitive identifier of a landform. The gray tones may be an indicator in certain situations. For example, two landforms which can be indicated by photo gray tones are the mottled gray tone of a young glacial ground moraine and the dull uniform gray tone in large field patterns representing glacial lakebeds. Study the photo gray tones; then describe the appearance and distribution of the photo gray tones for each suspected landform. A typical description is "light tones occur on cultivated open areas, dark tones where tree covered." Record this gray tone information in a photo pattern data element table for each unknown landform.

5.2.6 Land Use. Often the way in which humans influence the land can be correlated with a landform or soil type. Cultural features that are helpful in identifying landform/soil types include field tiles, ditches, levees, flood walls, gravel pits, orchards, contour plowing, and strip cropping. For example, the field tile pattern is associated with low relief features and it can indicate flat terrain with cohesive, fine-grained soils. Orchards are usually associated with well-drained landforms having granular soil. Also, landforms with coarse-grained soils are indicated by the presence of gravel pits. Well-drained uplands of dry, silty soil are often associated with certain crops such as wheat. Bedrock of economic value, like limestone, can be identified by vertical-walled quarries. The land-use patterns observed on the photo should be recorded in a photo pattern data element table for each unknown landform.

5.2.7 Vegetation. Ground conditions, especially moisture availability and soil texture, can be inferred from the types of vegetation found in the study area. These inferred ground conditions provide information that aids in the landform identification process. At the photo scales generally available to the terrain analyst, only gross vegetation classes are easily interpretable. However, one may expect certain types of vegetation to occur only given certain soil site conditions. For example, jack pine and poplar trees are commonly found on well-drained soils such as sand and gravel. Spruce, tamarack, sycamore, and willow trees are generally associated with landforms having wet soil conditions. Moisture-tolerant trees such as white pine and aspen may be found on either dry sites with sandy soils or wet sites with silty-clay soils. The accuracy of inferences based upon the stereoscopic observation and analysis of vegetation should be field checked whenever possible.

The analyst should describe the general type and distribution of vegetation found in the study area. Descriptions should include statements like "pine forest, scattered trees where cultivated." Record vegetation information in a photo pattern data element table for each unknown landform.

Finally, the analyst compares the photo pattern data element descriptions with a matching landform selected from section 7. Based upon this comparison, identification of each unknown landform in the study area is usually possible.

A landform study example is provided in section 5.4 to demonstrate the use of a data base for synthesis of pattern elements and the delineation and identification of landforms on a factor overlay.

5.3 Landform Delineation and Identification. A priori background information provides an initial list of landforms to expect in the study area. With these choices in mind, the analyst delineates the landforms on the factor overlay by visualizing the boundaries of each landform. For example, the analyst studying a coastal plain would delineate landforms such as tidal river flats, alluvial plains, and terraces. Using a pen (permanent fluid), the analyst marks boundary lines on the overlay sheet in order to separate landforms. These lines represent the visualized partitions between landforms.

The production of a landform factor overlay begins with the registration of the mylar sheet with the air photo mosaic. The next step is to search for elevation ranges and contour spacing data representative of each landform. Elevation labels in appropriate places on the overlay help the analyst distinguish the partitions between landforms. [illegible] searching for and establishing the appropriate [illegible] contour spacing provides the best indication [illegible] formation. [illegible] landforms have [illegible] contour [illegible] flat, [illegible] tilted landforms. [illegible] plains [illegible] contour spacing, while [illegible]

spacing. Contour line spacing along the drainage ways is also a landform indicator, as the contour lines are more dense parallel to the drainage channels for the higher terraces.

Boundaries on the landform factor overlay are marked where tonal and topographic changes are apparent. Usually, tonal and topographic changes occur at terrain and slope breaks, where one landform surface interfaces with another. These breaks enable the analyst to visualize boundaries for separating landforms. Stereoscopic viewing allows the analyst to observe relief-change locations between contrasting light to dark tones that represent change in vegetative cover. Also, it is useful to observe the mosaic and the topographic map alternately for these tonal and topographic markings.

Similar conditions can be observed on both topographic maps and photo mosaics while marking boundaries to separate the more level forms. A low density distribution of gullies is representative of flat or generally level terrain with low relief. Irregular surfaces, scattered wooded areas, and urban built-up terrain assist in locating boundaries. Irregular relief due to deeper, more frequent gully systems indicates the more irregular upland surfaces. When viewed stereoscopically, the slope break-tone contrasts are indicative of relief differences in the predominant features.

The terrain analyst combines all of the observed delineations into one factor overlay representing boundaries of landforms. Discrepancies between the positions of boundaries can be resolved in a rational manner. See the example given in section 5.4 below that demonstrates the delineation process. A field check procedure is organized as an option for verification of landform boundaries, vegetation types, engineering soil characteristics, etc. If the field check is not possible, then verification by additional photo interpretation is important.

5.4 Example: Landform Study

5.4.1 Geography. The study area location, in this case the terrain in the vicinity of Fort Belvoir, Virginia is in the United States and therefore easily found on a state road map, a geographic atlas, or a USGS topographic map at a scale such as 1/250,000. Outside the United States, study areas can be located on geographic atlases or topographic maps. Features that should be noted are province and/or state boundaries, country boundaries, urban areas, major roads, and railroad lines. Topography, which refers to the natural and culturally-induced variations in land levels, can be extracted from a USGS Quadrangle, a 1/50,000 U.S. Army Topographic map, or a foreign topographic map of similar scale for the particular area in which the landform study is to be conducted. For the Fort Belvoir study area, this type of information is extracted and described in this section in the order shown in table 5.1. An example of the extracted information on geography follows.

Example - The study area is located in Fairfax County, near Fort Belvoir, Virginia some 10 to 15 miles south of Washington, D.C. The population of the county, nearing 400,000, is primarily urban. The area is well served by transportation facilities including railroads, e.g., Richmond, Fredericksburg, and Potomac; major highways, e.g., I-95 and U.S. 1; and airports, e.g., National and Dulles International. Elevations of the terrain vary from lowland to high terrace locations, i.e., < 10 feet to 350 feet. In this terrain, agricultural areas are very limited and are decreasing as population density increases. Appendix B provides the 1/250,000 scale topographic map, one source for the above type of geographic information.

5.4.2 Climate. One of the best sources of information for establishing the climate of a given terrain is in the County Soil Survey published by the U.S. Department of Agriculture. Climate is given in the form of mean annual rainfall, mean annual snowfall, driest season, and percent chance of frost and period of occurrence. Further information may be obtained from hydrological and meteorological books and published papers. U.S. Weather and Defense Meteorological agencies offer additional sources of data. Typical climate information extracted for the study area is shown by the following:

Example - Fairfax County has a continental, humid, temperate climate. Temperatures vary seasonally, with an average difference of 36 degrees Fahrenheit between mean winter and mean summer temperatures; the average for the coldest month (January or February) is 37°F. Rainfall for the year is about 41 inches; in 1953, May had 7.4 inches and November, about 1 inch. Snowfall averages as much as 15 inches for a given year and is heaviest in January. The frost-free season is about 175 to 200 days; even so, the ground may be frozen to a depth of only a few inches. The soils of the county are quite suitable for crops adapted to these climatic conditions.

5.4.3 Physical Features and Landforms. The physical features of the earth are divided into the following physiographic units: division, province, and section. Also, topographic condition may be classified in terms of landforms. The extracted information of this nature for the Fort Belvoir study area, as presented on the Physiographic Diagram of the United States, is briefly described in the following example. Additional information is in appendix B.

Example - The study area, a portion of Fairfax County, Virginia, contains tidal river flats, alluvial plains, and terraces. These landforms are located within the Embayed Section of the Coastal Plain; simple, nearly flat structures

consisting of unconsolidated layers occur as recently elevated levels above the ocean floor. The flat topography of the plain imperceptibly grades easterly from the Piedmont section of the older Appalachian Province. This smooth, lowland plain, with good soil and climate, has ridges and hills parallel with the coast, often alternating between hard and soft rocks. The lowland formations of this portion of the Coastal Plain are weak and generally unconsolidated. Some areas, after rising and eroding, were submerged again, forming estuaries drowned by the sea; bays, some elliptical, were formed in low, flat coastal areas. The terrain, in general, varies from tidal river flats (basin) to high terraces.

5.4.4 Bedrock and Surface Geology. Two types of maps, structural and surficial, offer details on the bedrock and surface geology. The structural map symbols represent the underlying types of bedrock, and the surficial maps depict the surface features and spatial locations of the landforms, as well as providing brief but noteworthy information concerning the landform's origins. The geological data given in the following example were extracted from these types of maps.

Example - The bedrock underlying the sediments of the Embayed Section of the Coastal Plain consists of granite/gneiss, gneiss, and schist; near the fall line granite grades easterly towards the coast into gneiss. Fluvial sediments from the Coastal Plain deposits have buried the bedrock, and generally no outcropping occurs in the tidal flats, alluvial plains, or terraces. The bedrock systems are at sufficient depth to have no effect on landforms or photo patterns in the study area. The unconsolidated surface layers overlaying the bedrock consist of marl (lime), sand, silt, and clay with gravel.

5.4.5 General Soils. Generally state and other government agencies have a department of natural resources with a division of land and soil that will supply a general soils map on order. Often a soil survey is available on a county-by-county basis; this soil survey is published in cooperation with the U.S. Department of Agriculture Soil Conservation Service. The soil survey report usually notes the type of bedrock from which the soils are derived as well as the surface characteristics of the local soils. In most of the published surveys the soils are classified according to soil associations, which represent those soils having unique characteristics. The data for given associations, including soil type, drainage, slope, and land use of the study area, have been extracted from the Fairfax County Soil Survey, (for more detail see appendix B) as follows:

Example - The soil descriptions are based on associations derived

from the Coastal Plain sediments and are related by landforms. The alluvial plain and low tidal flats are covered with sand, silt, clay, and gravel of the Matapeak-Mattapex-Woodstown association. The intermediate and low terraces are occupied by Matapeak-Mattapex and Woodstown-Matapeak loamy, gravelly sediments. The high terrace is occupied by the LUNT-hilly and steep association and consists of loamy and gravelly sediments varying from west to east.

5.4.6 Hydrology and Drainage. Streams and rivers forming the major drainage channels are found in the study area. When possible, the type of drainage pattern is recorded for each watershed, and the succession of smaller to larger streams is noted. Identifying the pattern may be facilitated by searching for a match among those in figure 5.2. Typical data that are extracted from available hydrology reports (see appendix B) are given in the following example.

Example - The unconsolidated fluvial clays to gravels have a fairly well-developed drainage system, although there are some poorly-drained areas; the overall pattern tends to be dendritic. The tidal flat and alluvial plain landforms have meander systems. The low terraces have no general drainage pattern, and some wet areas are artifically drained for cultivation. The high terraces are characterized by the runoff pattern formed by the erosion of the unconsolidated sediments; small areas are poorly drained. All the surface runoff flows into drained channels that eventually empty into the Potomac River.

5.4.7 Vegetation and Land-Use. Most areas of the world have maps that show the distribution of vegetation that depicts the major forests from which the local vegetation has originated. For a particular area under study, the forest cover is noted from which tree species may be inferred. In the example used here the following data are extracted from the Soil Survey Report (see appendix B).

Example - Grasses and weeds occur in the marshland areas of the alluvial plains and lowland tidal zones. Forests occupy most of the terrace landforms. In the forested areas one may expect a mixture of hardwoods such as hickory, maple, beech, and poplar and softwoods such as Virginia pine. The forest understory consists of laurel, huckleberry, spicebush, red bud, and others. White oaks and red oaks and yellowpoplar are generally associated with the deep soils of the Coastal Plain. Sycamore, river birch, white elm, and willow occupy alluvial plains; white pin oak, scrubby white oak, and post oak grow in the lowland clayey soils.

Land-use information includes agriculture, woodlots, forests, orchards, gravel pits, and others. Also the location of urban areas and residential structures are recorded. In this example the Fairfax County Soil Survey provides the descriptive materials (see appendix B), a source of the extracted data shown below.

Example - In general there is a mixture of industry and agriculture with urban and military facilities occupying the landforms. Transportation facilities are adequate with major roads, railroads, and airports serving both commercial and residential facilities. Schools, colleges, churches and other facilities are adequate. The population growth is steady, with a good labor market available for government and industry. Generally there is no threat to the economic development of this area.

5.4.8 <u>LANDSAT</u>. LANDSAT data recorded in digital form and converted to black and white images are available from EROS Data Center, Sioux Falls, South Dakota. When these images are ordered in print format (copies are in appendix B), specify winter acquisition dates, bands five and seven at 1:250,000 scale. This source of information can provide a useful, synoptic view of major drainage systems, land-use patterns, and general landforms. Data extracted for the study area are given below.

Example - The study area is of diverse character as evidenced by the variation in gray tones observed on band-five and band-seven images of LANDSAT. One area of uniform dark tone is found to be a large drainage channel, the Potomac River. This channel is especially noticeable on the band-seven print because of its black tone. All the drainage channels are shown to be flowing toward the Potomac River. The image of the high terrace landform exhibits the dendritic drainage pattern. The region contains large urban areas that appear in lighter gray tones on the band-five image. The large undeveloped rural areas appear darker because of the vegetation. The agricultural fields are identifiable by their rectangular shapes and variable tones, from light to dark depending on the stage of crop growth, soil type, and moisture conditions.

5.4.9 <u>Airphoto Index</u>. Photo indexes for areas in the United States can be ordered from the U.S. Department of Agriculture, Production and Marketing Division, Salt Lake City, Utah. Foreign, as well as some U.S. indexes, can be obtained from the Defense Mapping Agency Hydrographic/Topographic Center (DMAHTC) Washington, D.C. The photo index sheet, usually at 1/63,000 scale, providesthe identity of stereo photos to be ordered. It also aids the analyst in the discernment of landform and land-use features. An example is given on the next page to show how the

photo index (see copy in appendix B) is used.

Example - The photo index for the Fort Belvoir area was obtained from DMAETC. From this index photos S1-8(37-41) and S1-8(42-46), at 1/40,000 scale were ordered. The index was also used for a synoptic view similar to that observed on LANDSAT of the major landforms, regional drainage patterns, and transportation and other facilities.

5.4.10 The Data Base Summarized. The short narrative description given below is a summary of specific data base information extracted from literature, maps, and imagery. The Coastal Plain is a simple, nearly flat structure consisting of unconsolidated layers of marl, sand, silts, and clay recently elevated above the ocean floor. On the western edge at the Piedmont the Coastal Plain begins and grades imperceptibly in an easterly direction to the coast. This relatively smooth surface has ridges and hills parallel with the coastline, often alternating between hard and soft rocks. The low to high level forms consist of tidal river flats, alluvial plains, and low, intermediate, and high terraces. Next the analyst begins the detailed analysis phase of the study area.

5.4.11 Air Photos, Stereo Coverage. Air photos can be obtained from the U.S. Defense Mapping Agency, Hydrographic/Topographic Center, 6500 Brookes Lane, Washington, D.C. 20335; Aerial Photography Field Office, ASCS-USDA, 2222 West 2300 South, P.O. Box 30010, Salt Lake City, Utah 84125; U.S. Geological Survey, EROS Data Center, Sioux Falls, South Dakota, 57198; and U.S. Geological Survey National Cartographic Information Center, Reston, Virginia, 22092. For the air photo analysis portion of the study, air photo scales from 1/20,000 to 1/40,000 are the most efficient; smaller scales can be used, but the amount and accuracy of data on landforms diminishes with the scale. The example given below identifies the airphoto coverage (see appendix B) used, followed by the type of data extracted during the stereophoto study.

Example - The 1/40,000 scale air photos for the study area are identified as S1-8(37-41) and (42-46), dated 27 Oct 72. These airphotos are used in stereo and mosaic form. During the stereoscopic observation, the Photo Pattern Data Element information is extracted for each anticipated unknown landform. To illustrate this procedure, examples of information extracted for the landforms of the Fort Belvoir study area follow (figure 5.4). Note that the extracted data elements are listed in the format suggested in table 5.2.

5.4.12 Topographic Maps. U.S. Geological Survey (USGS) quadrangle sheets are obtained from the National Cartographic Information Center, Reston, Virginia 22092. Topographic maps at 1/50,000 scale are ordered

[illegible]	
ELEMENT	DESCRIPTION
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible] habitat
[illegible]	Most [illegible] passable

[illegible] PATTERN STATEMENT [illegible]	
ELEMENT	DESCRIPTION
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible] shaped [illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

[illegible] PATTERN STATEMENT [illegible] Terrace [illegible]	
ELEMENT	DESCRIPTION
[illegible]	[illegible] bench-like elevation [illegible]
[illegible]	[illegible]
[illegible]	Variables
[illegible]	Bench-like surface and [illegible]
[illegible]	[illegible]
[illegible]	[illegible] preserve
[illegible]	[illegible]

[illegible] PATTERN STATEMENT [illegible] Terrace [illegible]	
ELEMENT	DESCRIPTION
[illegible]	[illegible] elevation [illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible] elevation [illegible]
[illegible]	Most [illegible]

[illegible] PATTERN STATEMENT [illegible] Terrace [illegible]	
ELEMENT	DESCRIPTION
[illegible]	[illegible] elevation [illegible]
[illegible]	[illegible] bench [illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible] flat predominantly [illegible]

Figure 5.4 Study Example of Landform Descriptions

from the Defense Mapping Agency, Hydrographic/Topographic Center, Washington, D.C. 20335.

The pertinent types of topographic information obtained from USGS quad sheets and/or U.S. Army map series are as follows: maximum and minimum elevations of the terrain, with ranges of elevations, contour spacing, and densities for each separate landform being noted; natural features as they relate to vegetation cover; the stream patterns, meanders, and gradients; and the cultural features such as roads, railroads, airports, land use, and extent of rural and urban areas and other features. All the pertinent information assists in preparation of the Photo Pattern Data Element descriptions. The maps used (see appendix B) and an example of the data extracted for the Fort Belvoir study area follow.

Example - The topographic maps at 1/24,000 scale for the study area are the Fort Belvoir, VA-MD and Annandale, VA sheets; the 1/50,000 scale U.S. Army topographic sheet is Indian Head, MD; VA, sheet 5561 II, Series V733. The maximum elevation for the study area is about 350 feet with the minimum at low tide approximately a foot or so above mean sea level (MSL). The elevation ranges for the several landforms are tidal flat, $<$ 20 feet; alluvial plains, 20 to 40 feet; low terrace, 20 to 100 feet; intermediate terrace, 100 to 170 feet; and the high terrace, 170 to 270 feet with some scattered locations reaching the maximum as given above. Vegetation cover consists of forests to scattered wood lots with some swampy or marshland areas indicated. One major stream, the Potomac River, flows through the study area. The streams and large creeks are double-lined on the map in areas with less than 100-foot elevation; hence they can be classed as rivers. Elsewhere there are numerous minor streams. At the lower elevations, such as near tide level, the streams meander considerably. The contour spacing varies from widely spaced, which represents the flat-topped terraces, to densely spaced, which indicates the steep slopes. Many state and county roads crisscross the study area along with major interstate routes connecting the important local urban areas. Major rail lines, with north-south and east-west orientations, traverse the study area terrain, serving the diverse land use, which varies from urban to rural in character. The cultural land cover is scattered farmland to residential, commercial, and industrial; military reservations occupy much of the land. Additional specific information related to each landform is given in figure 5.4.

5.4.13 <u>Landform Factor Overlay</u>. The earlier paragraphs have given the a priori background information and its revelation of landform expectations and the photo pattern data elements of each landform in the vicinity of Fort Belvoir. With knowledge of the expected landforms, the factor overlay delineation is begun. A description of the procedure for delineating the landform factor overlay is given as follows: The analyst locates and delineates the boundaries of tidal river flats, alluvial plains, and terraces. With the overlay mylar sheet registered to the airphoto mosaic and using a plastic marker (permanent fluid), the analyst delineates the boundaries of each landform, placing lines in position on the overlay that he visualizes as the separations or partitions for the landforms. An early step in the procedure is to mark at strategic locations spot elevations for each landform; these elevations are read off the topographic map and placed in corresponding locations on the mosaic/overlay for the analyst while distinguishing the several unknown landforms. For example, the tidal river flat has elevations less than 20 feet; these are placed on the overlay in spots recognized as part of the tidal river flats. At the next level, elevations between 10 and 40 feet are used to distinguish the alluvial plain; the analyst uses the wide contour spacing and pattern of stream channels to depict this terrain level. The low and intermediate terrain landforms, from low to high level respectively, occupy locations within the 20- to 100- foot contours and 100- to 170- foot contours. The high terraces occupy elevations higher than 170 feet. Again, for these ranges of elevations the contour spacing assists with discriminating the terrace locations. The terrace landforms have the more dense contour spacing, whereas the alluvial plain and tidal flats have the wider contour spacing. The midterrace landform contours have the intermediate spacing. The relative contour spacing density along drainage ways is also an indicator; the contours are closer together in the upper terraces and further apart in the tidal river flats.

The landform boundaries are observed on the airphoto mosaic and marked on the overlay where tonal and topo changes occur. Usually useful tonal/topo changes are formed at the terrain slope breaks, where the higher surfaces change to lower terraces or the lower terraces change to tidal river flats. The topographic/tonal breaks provide the boundary lines between the landforms. When the terrace/tidal flat boundary line is being marked on the overlay, the analyst visualizes the topographic break while looking through the steroscope for the relief change. The analyst also looks for the contrasting dark/light tones representing the forest cover versus grassland cover occurring at the tonal/topo break. The airphoto mosaic and the topographic map are observed alternately for these tonal/topographic markings.

Similar observations are used for separating terraces. The flat, generally level terrain with low relief and low-frequency gully distribution represents the low terraces. This terrain is contrasted with the higher irregular-surface of the high terraces of both scattered wooded areas and urban built-up terrain. The deeper more frequent gully systems

contribute to the irregular relief that is characteristic of this terrain. The analyst visualizes these tonal/topographic contrasts and marks on the overlay the lines that represent the boundaries between upland and terrace. Stereoscopically, the slope break-tone contrasts are based on observing relief differences in the predominant features. The Fort Belvoir landform overlay at reduced scale is shown in figure 5.5.

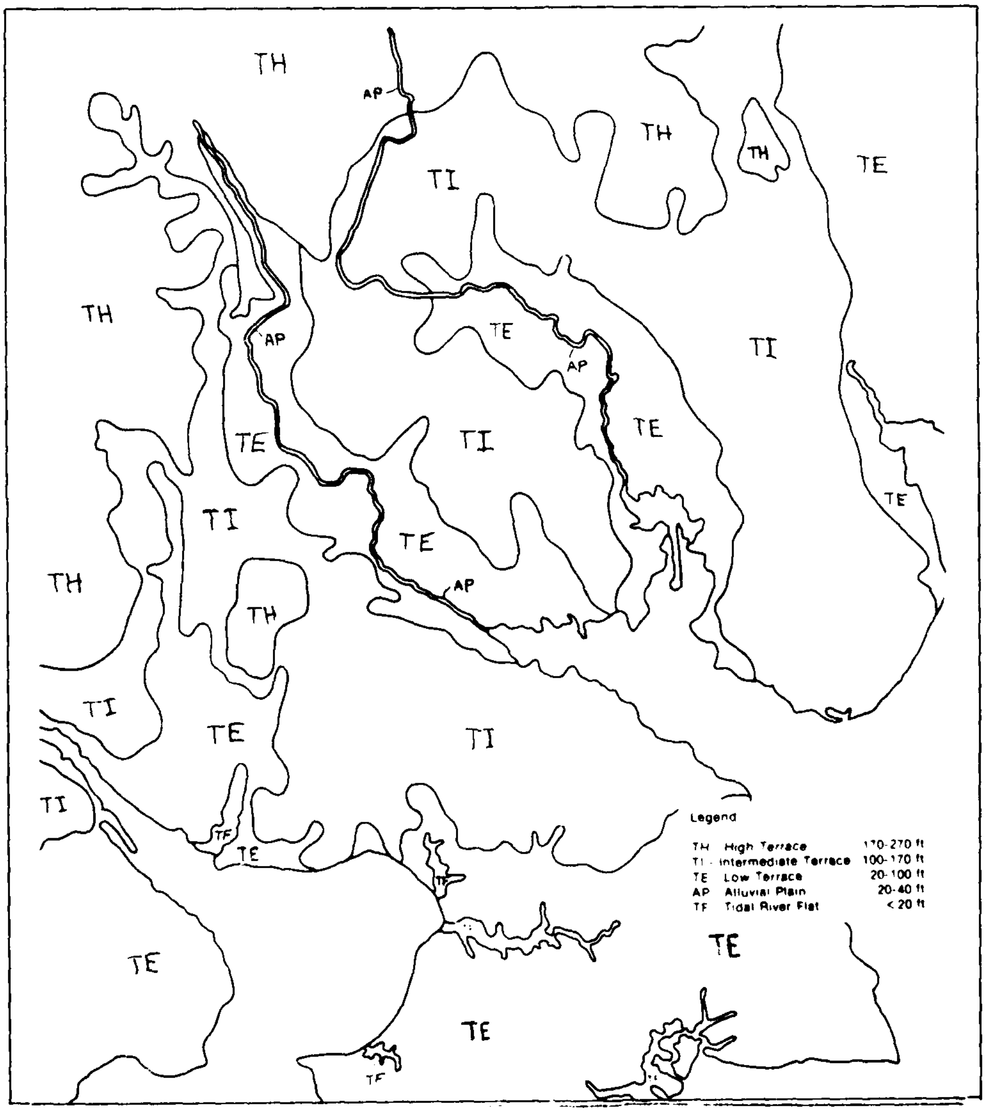


Figure 5.5. Landform Factor Overlay.

6. SURFACE ROUGHNESS ANALYSIS METHODS

6.1 General.

Surface roughness, as used in this guide, refers to all surface irregularities that are too small for mapping because their heights are less than the map contour interval. For a typical 1:50,000 scale topographic map with a contour interval of 20 meters, all linear or areal irregularities with a height of greater than 1.5 meters but less than 20 meters are referred to as surface roughness.

The analyst is concerned with one of two approaches in arriving at a surface roughness index (SRI). The first approach, outlined in section 3.0, is a fast means of determining surface roughness and utilizes the experience of the analyst along with the assigned landform SRI values that appear in section 7 of this guide. This approach will probably be used by the analyst after familiarity is gained with those landforms included in section 7. The second approach, detailed here in section 6, is based upon quantitative measurements taken from topographic maps and/or aerial photos. This approach should be used by analysts unfamiliar with either the given study area or section 7, and also in special situations where the analyst is unsure of the estimated SRI for a given landform or portion thereof.

The second approach consists of two SRI analysis methods: the topographic map technique and the airphoto analysis technique. The end product of either analysis is the SRI, which is a measure of the number and frequency of occurrence of irregularities of less than a map contour interval for a given landform. The numbers shown in the SRI overlay legend (figure 6.1) correspond to various levels of surface roughness (the higher the number, the greater the roughness).

6.2 Surface Roughness Factor Overlay Procedure.

The determination of surface roughness requires the services of a skilled terrain analyst, who visualizes the landform's surface roughness and makes inferences concerning the existing irregularities. For example, some landforms commonly contain erratics or boulders that are not mapped topographically and are even too small to be seen on aerial photography. When the analyst has correctly identified the landform, using the guidelines of section 5, he is able to infer the surface roughness in terms of the occurrence of boulders.

The tools available to the terrain analyst to accomplish this chore are typically the 7½ minute topographic quadrangle, or 1/50,000 scale topographic map, and aerial photography at a scale larger than 1/30,000. Obviously, the larger the scale of the photography, the greater is the detectability of surface roughness features. Informal studies have shown that there is perhaps an exponential increase in the observed number of

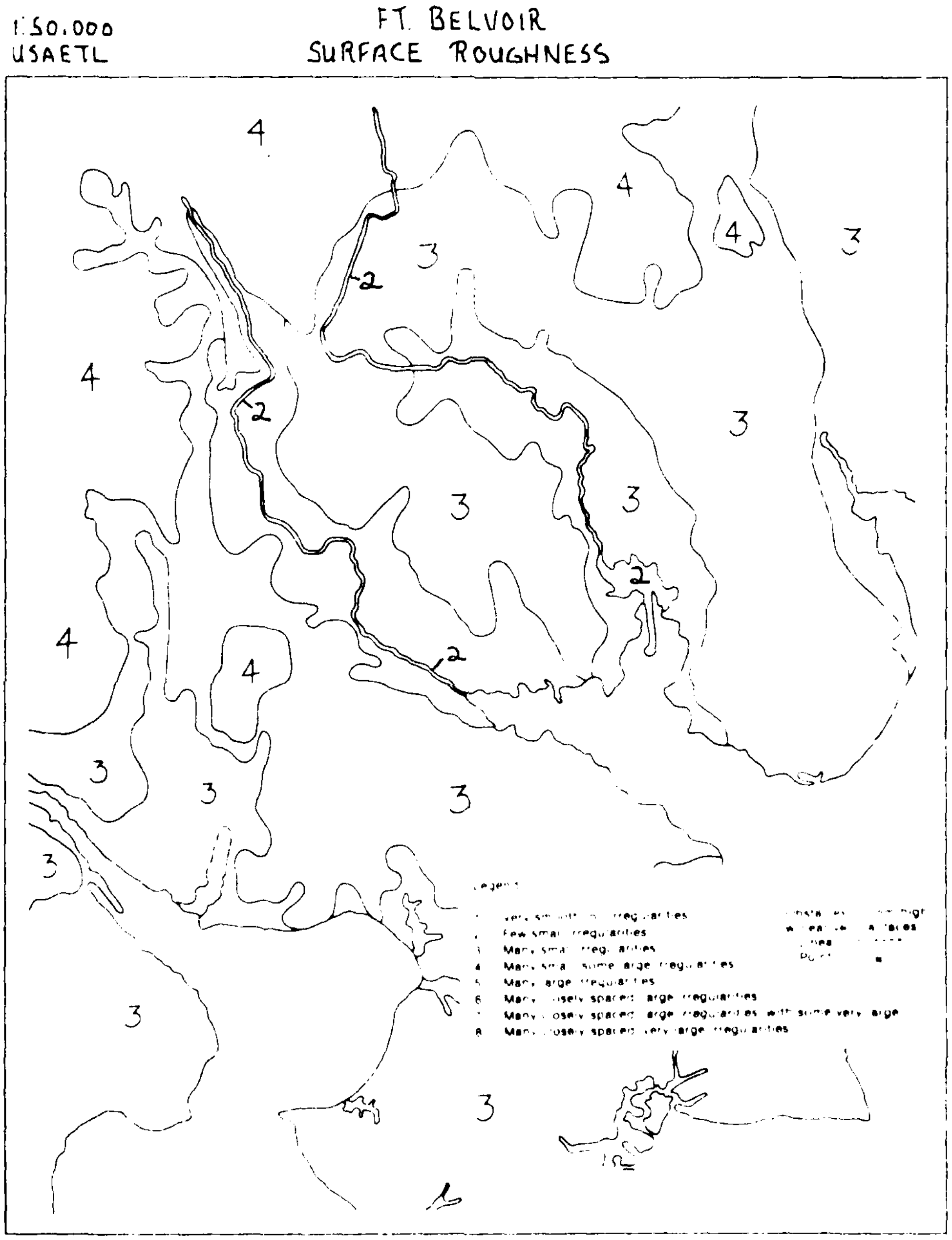


Figure 6.1. Surface Roughness Factor Overlay.

ground indicators of surface roughness as the photographic scale increases. Unfortunately, the aforementioned large-scale photography is not usually available to the terrain analyst. Therefore, inferences concerning surface roughness must be made by the analyst based on indicators, knowledge, and experience.

Using the guidelines in section 5 and working with the $7\frac{1}{2}$ minute or 1/50,000 scale topographic map, the terrain analyst identifies the landform. However, the topographic map does not give as much ground detail as does the aerial photography of similar scale. Therefore, these data sources are used together to determine the surface roughness. The topographic map provides an overview of the terrain, and the aerial photography provides the more detailed information.

The surface roughness overlay is prepared by first delineating and identifying areas of the terrain representing each landform. As shown in figure 6.1, the numerical SRI value then replaces the landform designation.

6.3 Obstacle Analysis Technique.

There are three general classes of land obstacles to be treated in this section: point, linear, and area. These features are ground obstacles only and are recorded on the surface roughness overlay. Obstacles related to surface drainage are shown on the watercourses and water bodies factor overlay. Point obstacles are features greater than 1.5 meters high with near vertical faces that are too small to be portrayed as an area obstacle. Linear obstacles are hinderances greater than 1.5 meters high with near vertical faces and are at least 2mm long at map scale (100m ground distance @ 1/50,000 scale). Area obstacles are ground features with greatest dimension of at least 2mm.

The obstacles under consideration are both natural and cultural. Natural obstacles include depressions, vertical-walled gullies, ridges and knobs, escarpments, boulders and erratics, and rock outcrops. Cultural obstacles include rock fences and walls, quarries and gravel pits, road and railway cuts/fills, hedgerows and retaining walls. Often these types of obstacles do not show up on 1/50,000 scale topographic maps or on aerial photos at scales smaller than 1/20,000. Because of this detectability problem, the terrain analyst needs to be familiar with the terrain types (landforms) in order to make the proper inferences as to the character and properties of observed obstacles.

The inference process requires an experienced terrain analyst who can recognize the landforms being observed in the airphotos. The analyst may not visually detect the smaller obstacles directly but infers their presence indirectly from his knowledge of the terrain type. For example, when a landform has been identified as a glacial end moraine, the experienced analyst then expects to find boulders, even though the

position of each boulder is not detected on the airphoto. In the case of a flood plain landform, once this type of terrain is recognized, the analyst will expect to find gravel pits with steep-walled areas, or steep-walled canals. Eolian landforms often contain steep, perhaps vertical-walled gullies and roadway cuts which commonly occur in loessial soil. Another example of this inference process occurs in limestone plains where the analyst expects to observe such features as rock exposed along roadway cuts, sinkholes, rock fences, and erratics. Sandstone and shale upland plains may also be expected to contain obstacles similar to those noted above.

In every case, the analyst must attempt to specifically locate all land obstacles and symbolize each with the appropriate symbol on the surface roughness overlay. If the available source materials are inadequate for detection of the smaller obstacles, a descriptive note should be provided which describes in general the types and locations of obstacles the user can expect to encounter.

6.4 Topographic Map Analysis Technique.

This section describes the topographic map analysis technique for finding SRI's of landforms. The technique involves the use of topographic maps to obtain quantitative, repeatable surface roughness measurements. These measurements of contour spacing, fence row frequency, number of contour bends, contour bend wavelength, and contour bend amplitude require the use of a grid and scale and are labled A,B,C,D and E respectively in table 6.1. After measured data are obtained, a surface roughness index is computed as shown later. The SRI provides a numerical index for the landform. A flow diagram of the topographic map technique for SRI derivation is shown in figure 6.2.

To facilitate the surface roughness measurement procedure, it is suggested that an identification number be temporarily assigned to each bounded landform on the overlay. This should make it easier to keep track of which landforms have been measured and also, in the case of a questionable SRI, it is possible to go back later and find the same landform. The following paragraphs discuss the method of obtaining measured surface roughness data from a topographic map.

6.4.1 Measured Data - For determining the measured data, an appropriate size grid is required (figure 6.3). The grid is prepared on a sheet of clear acetate and is composed of a number of cells, which are formed by the intersection of vertical and horizontal lines. The grid should be drawn with an extra-fine pen. The vertical lines are lettered AA-EE, and the horizontal lines are lettered FF-LL as shown in figure 6.3. Each grid cell should be 2.5 cm x 2.5 cm or approximately 1 inch x 1 inch (1 inch = 2.54 cm). The observation of measured data is based upon a standard, linear ground distance of 4000 feet. Since the length of a side of a cell represents 2000 feet, the measurements are made along the sides

Table 6.1. Format for Recording Topographic Map Surface Roughness Measurements.

Study Area: ____________.

Landform No.: ____________ Scale: ____________

Landform Type: ____________ Contour Interval: ________

Divide By	Line	A. Contour Spacing No. 5cm		B. Fence Row Frequency No./5 cm		C. Contour Bends No./5 cm		D. Contour Bend Wavelength (cm.)	E. Contour Bend Amplitude (cm.)
		1	2	1	2	1	2		
	AA								
	BB								
	CC								
	DD								
	EE								
	FF								
	GG								
	HH								
	II								
	JJ								
	KK								
	LL								
	MM								
	NN								
	Total								
	Average								

TOPOGRAPHIC MAP TECHNIQUE FOR SURFACE ROUGHNESS

I. Delineate and Identify Landforms of Study Area or Obtain Completed Landform Factor Overlay

↓

II. Obtain Topographic Map(s) of Study Area

↓

III. Measure Surface Roughness Properties of Each Landform

Measured Properties:

A. No. of Contour Lines/1.2 KM

B. No. of Fence Rows/1.2 KM

C. No. of Contour Bends/1.2 KM

D. Contour Bend Wavelength

E. Contour Bend Amplitude

↓

IV. Calculate Surface Roughness Index (SRI)

$SRI = E/D \sqrt{A+C} + 0.1(B)$

Figure 6.2. Flow Diagram of Topographic Map Technique for SRI Derivation

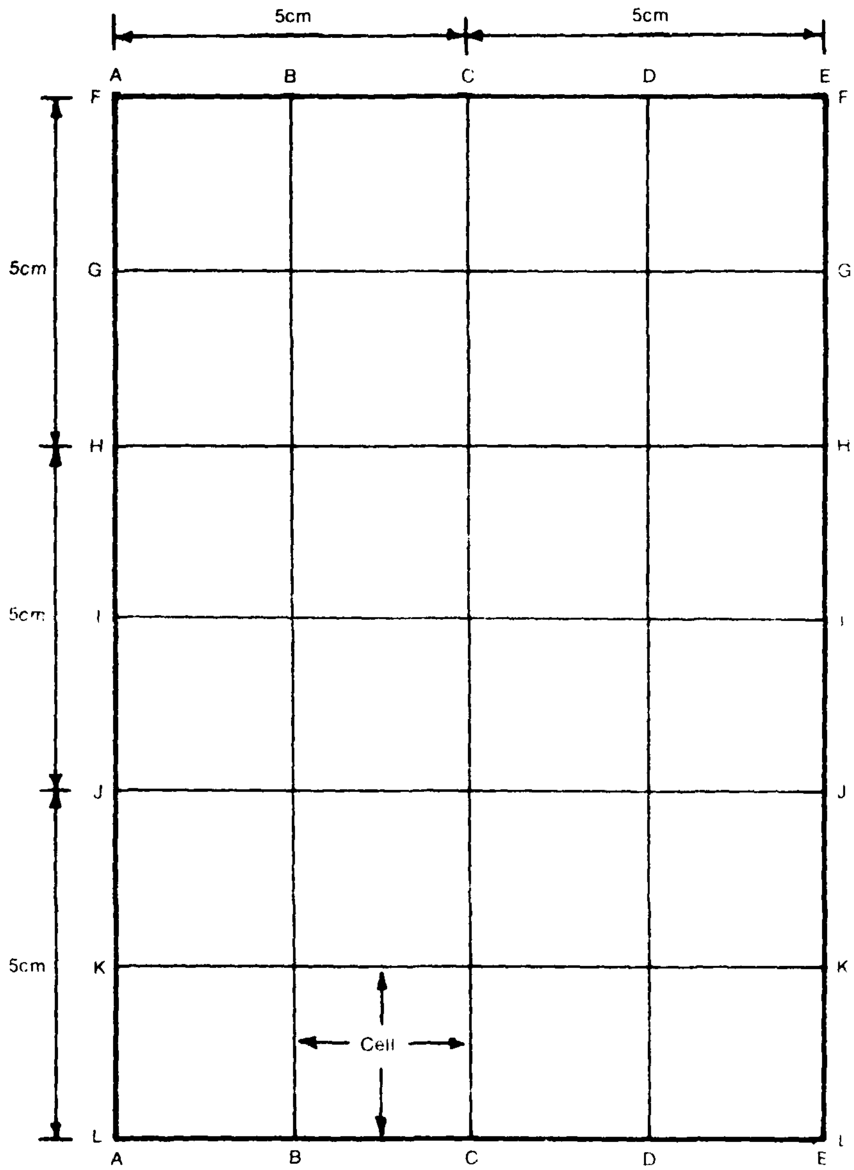


Figure 6.3. Grid Used With 1:24,000 Scale Topographic Map

two cells. For topographic maps with other scales, the grid must be asjusted according to the ratio given in Equation 6.1:

$$\frac{L_1}{L_2} = \frac{S_1}{S_2} \qquad (6.1)$$

L_1 = grid dimension for 1/24,000 scale

L_2 = grid dimension for scale of interest

S_1 = 1/24,000 map scale

S_2 = map scale of interest

The result of this calculation insures that the grid dimensions are properly adjusted for differences in map scale. As an example, consider the use of a topographic map with a scale of 1:50,000. The proper dimensions for the grid are determined by equation 6.1. Here S_2 = 1:50,000; thus the cell size L_2 can be computed as follows:

$$2.5\ \text{cm.}/_{L_2} = \frac{1/24,000}{1/50,000}$$

$$L_2 = 1.2\ \text{cm}$$

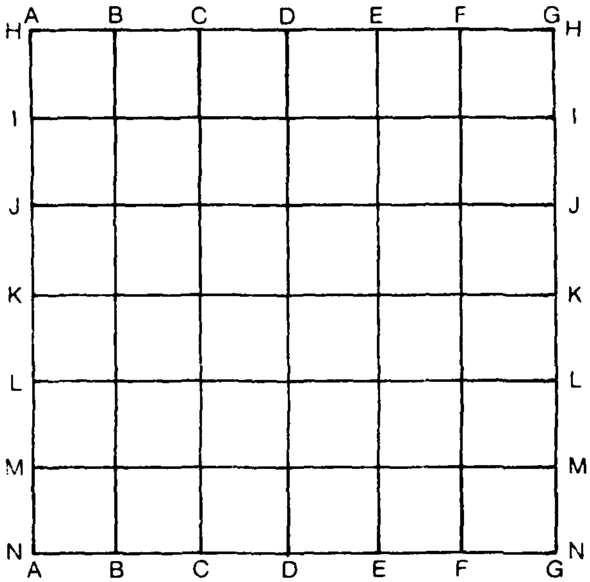
Grid dimensions for topographic maps of various scales are shown in table 6.2:

Table 6.2 Grid Dimensions for Various Map Scales

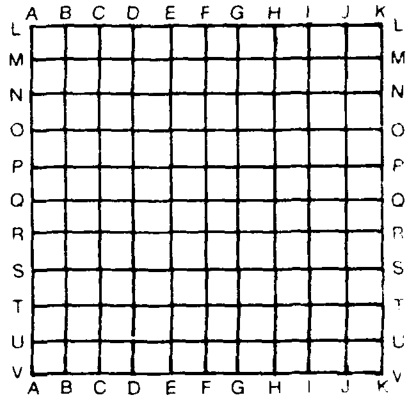
Scale	Length of Sides
1:24,000	2.50 cm.
1:50,000	1.20 cm.
1:62,500	0.96 cm.
1:125,000	0.48 cm.
1:250,000	0.24 cm.

These grids are shown in figures 6.3 and 6.4. In the following paragraphs the factors required in calculating the SRI are lettered A,B, etc. in the same sequence as shown in the columns of table 6.1.

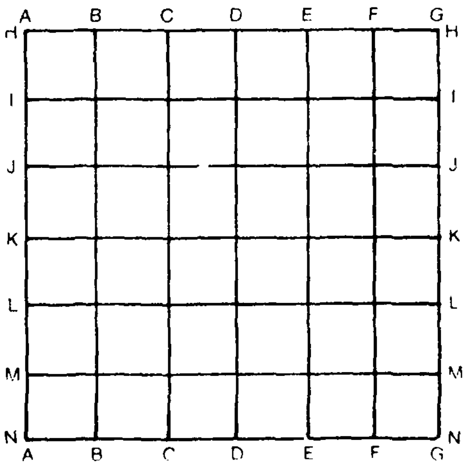
A. Contour Spacing - The grid on clear plastic is placed over representative portion of a given landform on the topographic map as in figure 6.5. Once the grid is in place, the edges of the clear plastic sheet are taped down to prevent the grid from moving. Then proceed as follows: count all contour lines crossing each vertical line ([illegible]) and horizontal line (FF-LL), divide the values obtained for [illegible] and FF-LL by 3 and 2, respectively, then total the values, and compute the



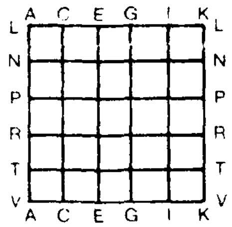
Grid Used with 1:50,000 Topographic Map



Grid Used with 1:125,000 Topographic Map



Grid Used with 1:62,500 Topographic Map



Grid Used with 1:250,000 Topographic Map

Figure 6.4 Grids Used with Various Topographic Map Scales

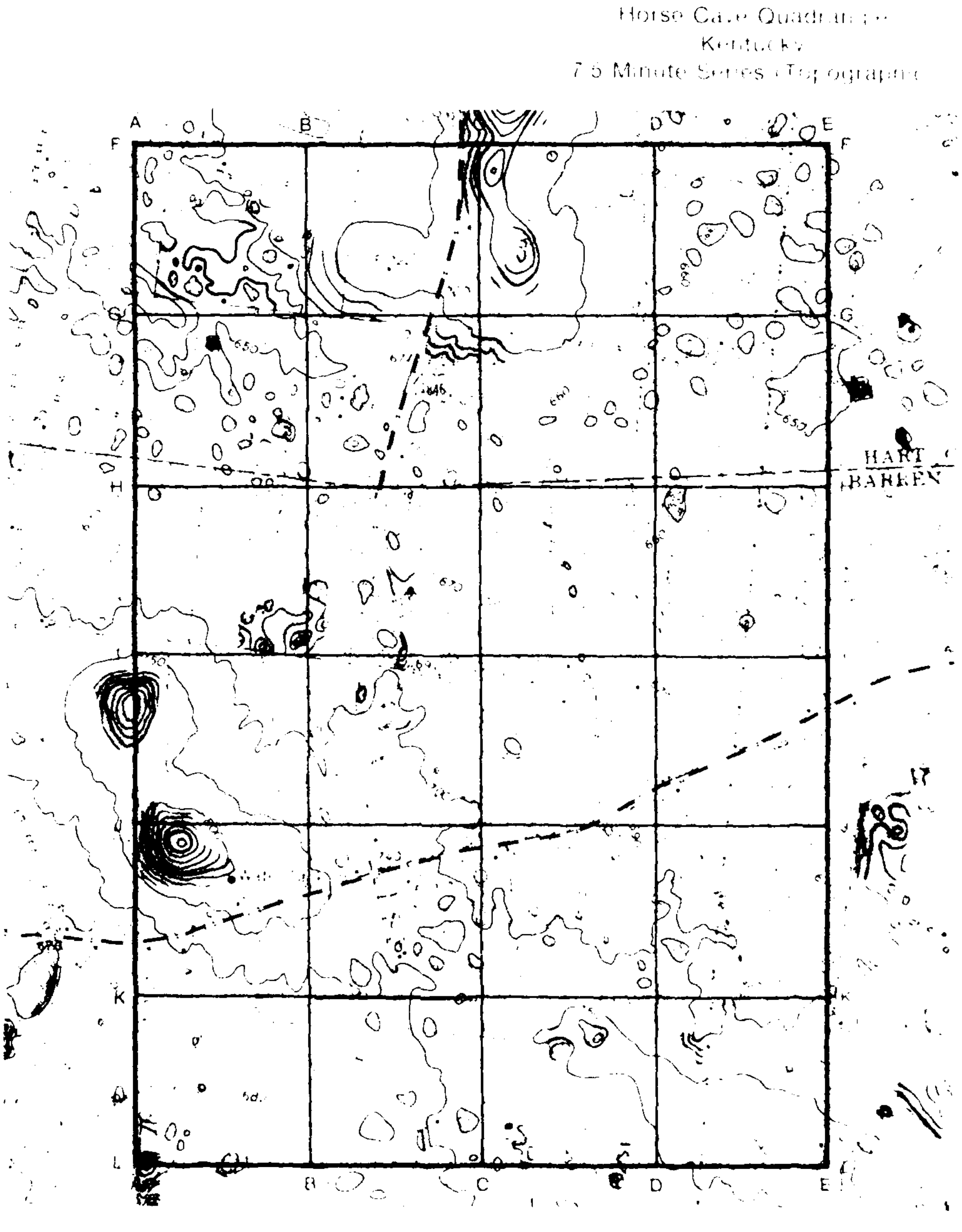


Figure [illegible] Grid Superimposed on a Portion of Horse Cave, Kentucky [illegible]

averages. The values should be recorded in a table as shown for the Horse Cave, Kentucky map sheet, table 6.3. Column A, contour spacing (in .75 cm.), is subdivided into two columns. Column A1 lists the number of times that each grid line is crossed by a contour line, and column A2 gives the contour spacing per 5 cm for each grid line. In this example, the limestone plain, there is an average of 17.1 contour lines per 5 cm.

It is not always possible to use the entire grid for a given portion of the landform. In that case, use a portion of the grid that satisfactorily covers the study area. The values recorded in column A1 are divided by the proper number as shown in the left-hand column to obtain the number of contour lines per 5 cm. For example, if there are only 4 horizontal grid lines, i.e., FF-II, the values of column A1 for AA-EE are divided by 1.5. If necessary, the grid overlay can be expanded to cover more map area. Also, one must be careful to note the contour interval on the topographic map. The technique explained here has been developed for the 10-foot contour interval as a standard, but for any other contour interval a correction will be required. For example, if given a topographic map with a 50-foot contour interval, the final average in column A is multiplied by 5. Here one counts all the contour lines intersecting vertical and horizontal lines on the grid overlay.

B. Fence Row Frequency - Fence rows, as used in this guide, refer to all linear manmade features that occur on the surface of the terrain. These features include true fence rows that usually represent property lines and are denoted on the USGS 1:24,000 scale topographic map by red dashed lines. Also grouped in this category are roads, telephone lines, pipelines, and power lines. The measurement procedure followed is the same as the one discussed for contour spacing, except that fence rows are counted. For example, the limestone plain has 3.2 fence rows per 5 cm (see table 6.3). It is noted that true fence rows are not depicted on U.S. Army 1:50,000 or smaller scale topographic maps.

C. Number of Contour Bends - Using the grid placed on the map, select one contour line within each cell. The selected contour line should intersect opposite grid lines. For each contour line, count the number of bends within a grid. This value represents the number of bends per 2.5 cm. Record these values as shown in column C1 of table 6.3. It is not necessary to include every cell and it may be impossible to do so for some terrain. Although the precision will be enhanced with a greater number of measurements, be sure a representative sample of the landform is used. To obtain the number of contour bends per 5 cm, double the results of column C1 and record these values in column C2. Then total column C2 and compute the average. As measured and recorded in table 6.3, the limestone plain has 25.5 contour bends per 5 cm.

D. Contour Bend Wavelength - As with the contour bends, select a representative cell sample, where one wavelength measurement may be made. The measurement, which represents the distance between the peaks of the

Table 6.3. Topographic Map Surface Roughness Measurements — Horse Cave, KY.

Study Area: Horse Cave, KY

Landform No.: 1 Scale: 1:24,000

Landform Type: Limestone Plain Contour Interval: 10ft

Divide By	Line	A. Contour Spacing No./5cm		B. Fence Row Frequency No./5 cm		C. Contour Bends No./5 cm		D. Contour Bend Wavelength (cm)	E. Contour Bend Amplitude (cm)
		1	2	1	2	1	2		
3	AA	55	18.33	12	4.00	14	28	.200	.200
3	BB	38	12.66	8	2.66	15	30	.500	.110
3	CC	49	16.33	12	4.00	14	28	.300	.060
3	DD	61	20.33	8	2.66	18	30	.210	.160
3	EE	66	22.00	6	2.00	8	16	.300	.200
2	FF	37	18.50	8	4.00	11	22	.500	.100
2	GG	36	19.00	10	5.00	10	20	.300	.100
2	HH	27	13.50	5	2.50	8	16	.400	.280
2	II	34	17.00	5	2.50	15	30	.300	.200
2	JJ	37	18.50	8	4.00	15	30	.200	.300
2	KK	33	16.50	1	0.50	12	24	.300	.180
2	LL	28	14.00	8	4.00	13	26	.300	.100
	MM								
	NN								
	Total		205.65		37.82		306	3.810	1.990
	Average		17.1		3.2		25.5	0.32	0.17

bends (figure 6.6), is determined with a centimeter scale. Take several measurements and record these values and totals as shown in column D of table 6.3; then compute the average. The average wavelength for topographic maps of scales other than 1:24,000 must be adjusted. For example, on a topographic map with 1:62,500 scale, the average wavelength is computed as 0.10 cm; the adjusted average wavelength is obtained by the proportion shown below.

$$\frac{X}{0.10 \text{ cm}} = \frac{1/24,000}{1/62,500}$$

$$X = \frac{62,500}{24,000} (0.10 \text{ cm.}) = 0.26 \text{ cm.}$$

E. Contour Bend Amplitude - This procedure requires measurement of the amplitude of representative contour bends (figure 6.6). For the example being used, the values obtained for the amplitude measurements are recorded as shown in column E of table 6.3. In this case, the average amplitude for the limestone plain is 0.17 cm. Note: It is a good idea to measure the amplitude on the contour bend on which the wavelength measurement was made.

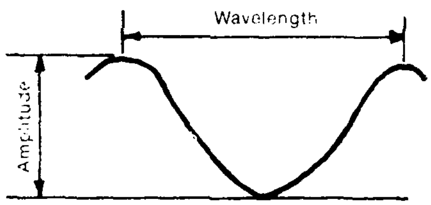


Figure 6.6. Wavelength and Amplitude of a Contour Bend.

6.4.2 Surface Roughness Index (SRI) from Topo Map Measurements - The SRI is calculated from the following equation:

$$SRI = E/D \sqrt{A+C} + 0.1 \text{ (B)} \qquad (6.2)$$

Where A = No. of contour lines per 5 cm. or per 1.2 km.
B = No. of fence rows per 5 cm. or per 1.2 km.
C = No. of contour bends per 5 cm. or per 1.2 km.
D = Contour bend wavelength (cm.)
E = Contour bend amplitude (cm.)

Equation 6.2 was developed for the 1/24,000 scale topographic map. The terms within the equation have to be weighted differently for smaller scale topo maps where the detail is sparce. The contour detail parameters, A and C, are summed together and considered to be an exponential function. This term is then multiplied by the ratio of the contour bend

amplitude to the contour bend wavelength. The amplitude term reflects the degree to which the terrain is undulating. The higher the numerator, the higher is the value for the SRI representing the surface roughness. The measured value for wavelength to a large extent depends on the density of the gully pattern; this value is in the denominator; hence, the smaller the value of this term, the greater is the surface roughness. In combination, larger values of amplitude and the smaller values of wavelength result in greater SRI values. The term for fence row frequency is identical to that found in the equation used in the airphoto analysis technique, as will be shown later.

Surface roughness index values will vary for a given landform. For example, if the grid is removed after an initial SRI evaluation and then replaced on the map for a second SRI evaluation, the grid placement will alter the measurements. The values for the contour bend wavelength and amplitude are the most variable because of the difficulty in observing a representative portion of the landform. The ratio of the amplitude and wavelength produced the largest effect on the final SRI value. But it is encouraging to note that the SRI values did not vary by an amount greater than ± 1 for consecutive map measurements. For instance, the initial SRI value for the limestone plain was found to be 3.79, as shown below, compared to a subsequent measurement giving an SRI = 3.38. Using equation 6.2 for the limestone landform, we calculate the SRI from the average of measurements noted in table 6.3 as follows:

$$\mathrm{SRI} = \frac{0.17}{0.32}\sqrt{17.1 + 25.5} + 0.1(3.2) = 3.79$$

The procedure shown above should assist the terrain analyst's understanding of surface roughness estimation by the use of the topographic map technique. The main advantage of this technique is that it provides a systematic process for calculating the surface roughness of various landforms as found on a topographic map. It should be emphasized, however, that equation 6.2 may need refining after testing at map scales different from 1/24,000; the present results are still somewhat tentative. As this systematic process is applied and as one becomes familiar with various landforms and their SRI characteristics, more consistent conclusions may be expected.

6.5 Airphoto Analysis Technique.

The analysis involves an orderly sequence of steps as follows:

1. The determination of an estimated SRI value based on the analyst's general expectation for a given landform resulting from his initial

observations of the airphoto patterns.

2. An airphoto analysis of surface roughness properties.

3. Calculation of SRI using equation 6.3.

A flow diagram that summarizes the airphoto technique for SRI derivation is given in figure 6.7.

6.5.1 <u>Estimated SRI from Airphotos</u>. The estimated SRI is determined as the analyst initially becomes familiar with the landform and its expression on the airphoto. The photography is scanned for those irregularities on the terrain that are directly responsible for ground surface roughness such as contour bends, gullies, point obstacles, fence rows, tonal changes, and linear obstacles--and each of these features is counted. As with the topographic map analysis technique, the analyst visualizes the landform as ranging from a smooth surface such as a lakebed (SRI = 1) to a rugged mountain (SRI = 8). The analyst estimates the character of the irregularities and assigns an SRI value. This estimated SRI can be derived more systematically as is shown in the following paragraphs.

6.5.2 <u>Calculating the Surface Roughness Index</u>. Equation 6.3 below is used to determine a surface roughness index from measurements on airphotos. The SRI value derived from this equation for a given landform will represent all the observed irregularities. As with the topographic map procedure, measurements are based on a standard distance of 4000 feet or 1.2 kilometers.

$$SRI = 0.1\left(\frac{a+b}{2}\right)^2 + 0.1\sqrt{c} + 0.1d + 0.2e + f \qquad (6.3)$$

where a = number of contour bends per 1.2 km

b = number of gullies less than 3 m wide per 1.2 km.

c = number of point obstacles per 1.2 km.

d = number of fence rows per 1.2 km.

e = number of tonal changes per 1.2 km.

f = number of linear obstacles per 1.2 km.

Parameters a and b in the equation represent related erosional characteristics, which are averaged together as a single term in the equation. These parameters are included as an exponential function to represent the degree of difficulty in traversing terrain with an increasingly dense pattern of contour bends and gullies. The same would be the case with the number of point obstacles. That is the degree of difficulty in traveling through terrain in which there is only one boulder per kilometer would essentially be zero. In fact, 10 boulders per kilometer would begin to present a problem, and 1000 per kilometer would present a significant, irregular surface roughness feature; i.e., the increase in degree of traverse difficulty would no longer be a linear function. The numbers of fence rows, tonal changes, and linear obstacles are considered

AIR PHOTO TECHNIQUE FOR SURFACE ROUGHNESS

I. Delineate and Identify Landforms of Study Area or Obtain Completed Landform Factor Overlay.

II. Prepare a Photo Mosaic of the Study Area.

III. Measure Surface Roughness Properties of Each Landform.

A. Prepare a Working Overlay of Erosion Lines. Count the Number of Contour Bends per 5 cm.

B. Obtain Completed Watercourses and Water Bodies Factor Overlay or Prepare a Working Overlay for Alignment of Watercourses and Water Body Shorelines. Count the Number of Watercourses with a Dry Gap Width of 3 Meters or Less per 5 cm.

C. Prepare a Working Overlay for Location of Outcrops and Erratics. Count the Number of Outcrops and Erratics per 5 cm.

D. Prepare a Working Overlay for Alignment of Fence Rows. Count the Number of Fence Rows per 5 cm.

E. Prepare a Working Overlay of Linear Obstacles. Count the Number of Linear Obstacles per 5 cm.

IV. Calculate Surface Roughness Index (SRI).

$$SRI = 0.1\left(\frac{a+b}{2}\right)^2 + 0.1\sqrt{c} + 0.1d + 0.2e + f$$

Figure 6.7. Flow Diagram for Air Photo Technique for SRI Derivation

to be represented by linear terms in the equation. The linear obstacle term, f, carries the most weight because it is considered to represent a surface with large (or very large) irregularities. The weights assigned to each parameter resulted from extensive trial and error and adjustments after testing the equation on several types of landforms, which range from a flat lakebed landform (SRI = 1) to a tilted interbedded sedimentary rock landform in an arid climate (SRI=8).

6.5.3 <u>Airphoto Data Elements</u>. Each of the following data elements is defined in the next paragraphs: (a) number of contour bends, (b) number of gullies, (c) number and location of point obstacles, (d) number of fence rows, (e) number of tonal changes, (f) number and location of linear obstacles, and (g) location of area obstacles.

a. <u>Contour bends</u> - Contour bends are counted by identifying the number of times the slope angle changes sign from positive (+) to negative (-) and vice versa, i.e., counting the undulations on the ground surface. A given terrain profile or cross section may have several slope changes as shown in figure 6.8 (the location of each slope sign change is indicated by a vertical dashed line).

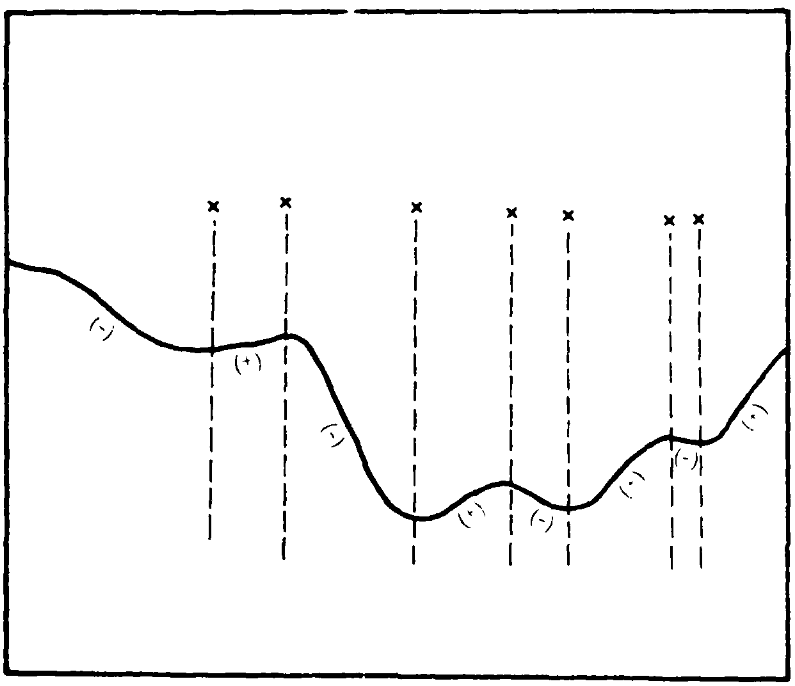


Figure 6.8 Slope Change as a Method for Counting Contour Bends

b. Gullies - Gullies are important in the surface roughness determination. Wet or dry, gullies are recognizable when airphotos are studied in stereo. A watercourse (gully) becomes a surface roughness feature when its dry gap width is 3 meters or less. Dry gap width is defined as that width of channel that contains the watercourse during both low- and high-water stages. The width is measured bank-to-bank, usually at the first slope break above water level as illustrated in Figure 6.9.

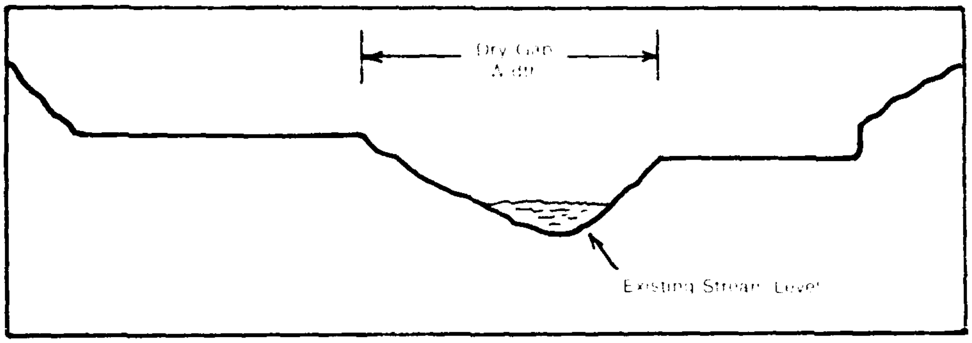


Figure 6.9. Illustration of Dry Gap Width

It is usually easier to study a gully system drawn on a separate overlay than to use it drawn on the photo itself. This is particularly true of complicated terrain. For a thorough analysis, all the gullies, tributaries, and primary watercourses should be carefully and faithfully traced onto an overlay. The first step in the analysis is therefore, the preparation of an overlay showing the drainage system for the study area. The second step in the analysis requires determination of where the 3-meter gap width begins upstream on each watercourse. This entails a detailed stereophoto study by the terrain analyst and calculation of what horizontal photo measurement is required to distinguish widths of 3 meters or less at the scale of the photography being used. This is accomplished by solving equation 6.4 for horizontal measurement,

$$\text{horizontal photo measurement} = \frac{xy}{z} \qquad (6.4)$$

x = dry gap width = 3 meters,
y = factor converting millimeters to meters = 1000 mm/m,
z = photo RF denominator = 24,000.

$$\text{horizontal photo measurement} = \frac{(3)(1000)}{24,000} = 0.125 \text{ mm}$$

i.e., dry gap widths of 3 meters measure approximately 0.13 millimeters on 1:24,000 scale aerial photography.

It is readily apparent that this small measurement cannot be achieved *using a conventional rule graduated* into 1 millimeter intervals. In order to quantitatively measure microrelief features, one must have

access to either very large scale photography or a micrometer scale. From table 6.4 it is seen that the smaller the scale of the photography, the smaller is the required measurement. Any scale smaller than 1:3,000 requires a measuring rule graduated in units smaller than 1 millimeter in order to define dry gap widths of 3 meters or less on aerial photography.

Table 6.4. Photo Measurements Required to Detect a 3 Meter Dry Gap Width at Common Photo Scales.

To detect a dry gap width of	At a photo scale of	Requires a photo measurement of
3 m	1 60 000	0 05 mm
3 m	1 50,000	0 06 mm
3 m	1 35 000	0 09 mm (approx.)
3 m	1 24,000	0 13 mm (approx.)
3 m	1 20,000	0 15 mm
3 m	1 15,000	0 20 mm
3 m	1 10,000	0 30 mm
3 m	1 5,000	0 60 mm
3 m	1 3,000	1 00 mm

c. Point Obstacles - These are small surface irregularities, greater than 1.5 meters high, that show a high amount of symmetry in plan view. They include such obstacles as erratics or native boulders, pinnacles, sharp-pointed ridge crests, pointbars, etc. They are often difficult to identify on aerial photography, and they require the terrain analyst to detect minute detail. A magnifying glass should be used for these observations. In addition, some landforms will exhibit certain types of point obstacles. For example, some glacial tills are characterized by the presence of boulders, often very large, completely foreign to the local bedrock. These boulders, large or small, are known as erratics. Often, native boulders are found in low-lying areas or on hillsides, which have broken away from strata lying somewhere on the slope above. These boulders are commonly found along mountain streams and may be very numerous; thousands may be present in a distance of only a few hundred meters.

d. Fence Rows - As explained in the topographic map technique, fence rows are representative of changes in property ownership and are often obstacles to cross-country movement, especially when built as rock walls or hedgerows. The lines are counted when observed on air photos, and their frequency is used in the surface roughness equation. In general, fence rows are not representative of relief except that in flat terrain they occur in straight line patterns and in hilly terrain they occur in irregular or curvilinear patterns.

e. Tonal Changes - Texture or tonal roughness is an aggregation of unit features each of which may be too small to be discerned individually on the photography. It is a product of slope, size, pattern, shadow, and tone. Tonal roughness may be quantified by evaluating its variability in terms of gray scale values within a unit area. A rough area would exhibit a large degree of tonal variance, whereas a smooth area would exhibit less tonal variance. To measure these tonal variations, the number of times the photography tones change in value is counted by comparing them with an uncalibrated Kodak Paper Gray Scale.* This scale is divided into ten reflectance values ranging from 0 percent (black) to 100 percent (white).

f. Linear Obstacles - These are elongated surface irregularities greater than 1.5 meters high with near vertical faces. Some examples include rock outcrops, sharp ridge crests, terrace edges, [illegible], gully walls (as occur in loess), and man-made obstacles such as quarries and roadcuts.

The most common linear obstacle is the rock outcrop. [illegible] result from mass wasting of less competent material adjacent to [illegible] strata, from faulting, and from excavation. Linear obstacles are [illegible] graphically expressed by a close grouping of contour lines, and [illegible] expressed on the photography as sharp breaks in slope. The apparent sharpness of the slope break can be affected by the [illegible] of surrounding vegetation. They may be expressed as linear features only [illegible] few meters long or they may be hundred of meters in length, [illegible] along fault zones.

g. Area Obstacles - These are obstacles which severely restrict land movement and include both natural and man-made features. Some examples are large quarries, boulder fields, strip mines, and terraced hills.

The airphoto pattern data elements having [illegible], the next step is to explain the measurement technique and [illegible] calculations to determine the Surface Roughness [illegible]

6.5.4 Airphoto Measurements. This method first [illegible] a grid on plastic composed of cells that give the [illegible] distance of 1.? [illegible] gives grid size [illegible] 6.11 are examples of grids prepared for 1/? [illegible] respectively [illegible] grid [illegible] drawn. [illegible]

*[illegible]

Table 6.5 Grid Sizes for Various Air Photo Scales.

Air Photo Scale	1/15 000	1:20 000	1:24 000	1:30 000
Amount of ground surface covered per inch of photo	1250 ft	1666 ft	2000 ft	2500 ft
Amount of ground surface covered per 5 cm of photo	2500 ft (0.8 km)	3332 ft (1.0 km)	4000 ft (1.2 km)	5000 ft (1.5 km)
Size of grid cells to give 1.2 km (4000 ft) standard ground coverage	8 cm	6 cm	5 cm	4 cm

Once the appropriate grid is prepared, it is placed over a selected stereopair then fastened with paper clips, and the observation and measurement of surface roughness data elements is performed. Each data element is counted or measured separately.* This step requires the use of a magnifier that includes a measuring scale within or a magnification device with separate scale. Along each line segment, A-A, B-B, etc., count the number of times that the data element transects the grid line. Then determine the frequency of occurrence per 1.2 km for the data element; i.e., the numbers obtained by counting along A-A, B-B, C-C, D-D, and E-E are each divided by 3, and the numbers obtained by counting along F-F, G-G, H-H, I-I, J-J, K-K, and L-L are each divided by 2. The final results are recorded in the format shown in table 6.1.

Details concerning observations and measurements for each separate data element follow. A fictitious set of numbers is used in the tables to illustrate the procedure.

a. Number of contour Bends. In plan view, these changes are noted by stereoscopically observing the photos for the number of slope sign reversals (undulations).

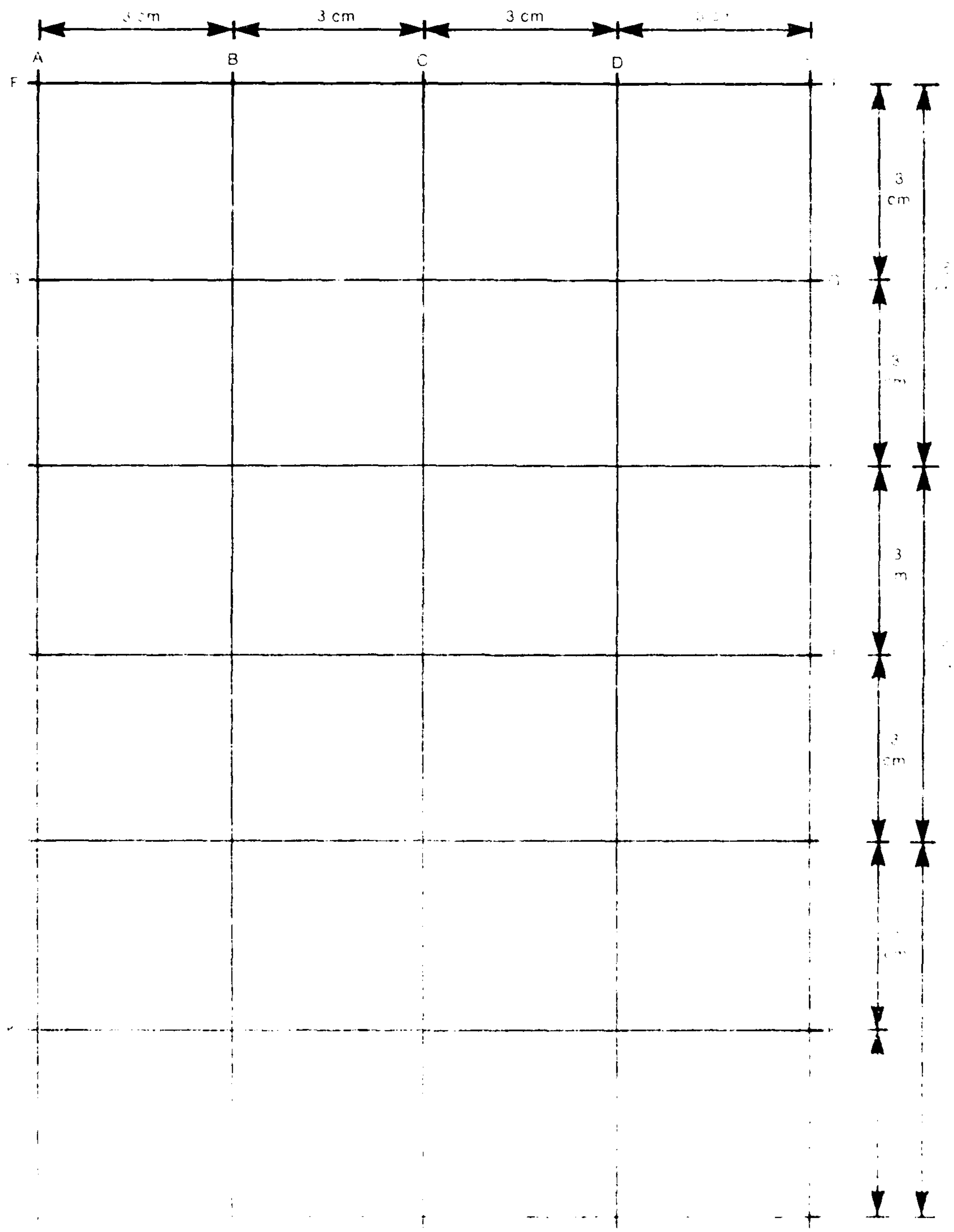
1. Prepare a table as given in table 6.6 for recording the data.

2. Place the appropriate size grid over the aerial photographs.

3. Stereoscopically study the photos and count the number of times the slope sign changes along each line, A-A, B-B, etc. Record these numbers as is shown in column II.

---

*NOTE: The decision whether to trace each data element on a working overlay or to count directly from the photo stereopair is made by the analyst; however, for point, linear, and area obstacles a working overlay should be produced to facilitate transfer of obstacle locations to the surface roughness overlay.


3 cm
3 cm
A
B
C
D
F

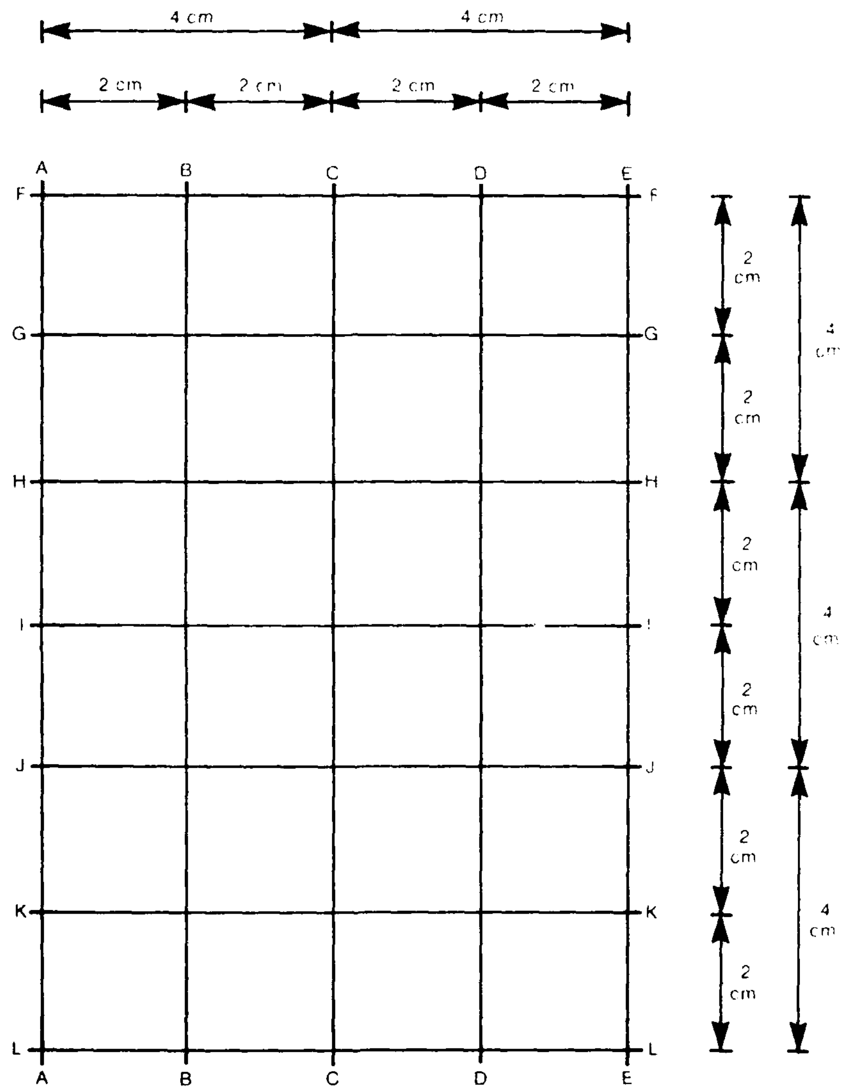


Figure 6.11 Grid for 1/30,000 scale photography (Each 4-cm grid represents 1.2 kilometers)

4. Calculate the number of contour bends [illegible] record the number as shown in column III.

5. Average the numbers as shown in column III, and record [illegible] value at the bottom of the column.

Table 6.6 Contour Bend Summary

I Line Segment	II # of Contour Bends	III # of Contour Bends [illegible]
A-A	35	11.7
B-B	17	5.7
C-C	26	8.7
D-D	39	13.0
E-E	11	3.7
F-F	6	3.0
G-G	24	12.0
H-H	22	11.0
I-I	20	10.0
J-J	17	8.5
K-K	24	12.0
L-L	8	4.0
		Average = 8.6

b. Number of Gullies. This [illegible] that gullies with dry run widths of [illegible] fied. This identification can be d[illegible] bodies factor overlay of the study [illegible] overlay constructed from [illegible]

1. Orient a microfe[illegible]

2. Beginning with [illegible] measures greater than [illegible] Mark with an arrow on the overlay [illegible] width narrows to 3 [illegible] less.

[illegible]

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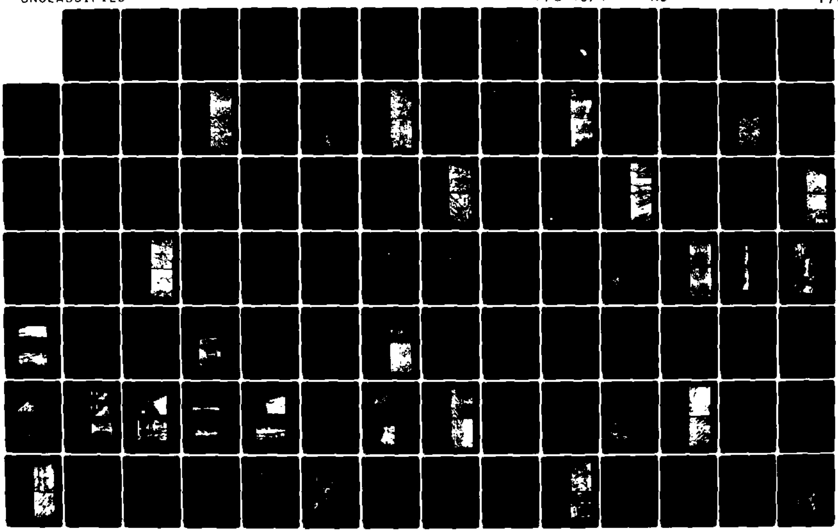
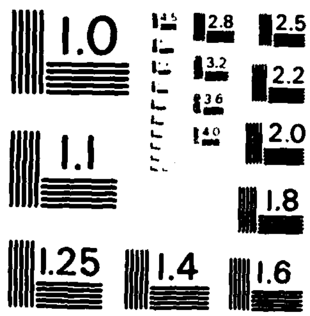



1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5

3. [illegible] the water [illegible] until [illegible] per [illegible]. Perform this procedure [illegible].

4. Prepare a table for recording the gully information [illegible].

5. Place a grid over the [illegible] terrain as shown in figure [illegible].

6. Along each line, count the number of times that a gully [illegible] meters or less transects the line, A-A, B-B, etc. Record this number as illustrated in column II, table 6.7.

7. Calculate the number of gullies having a dry gap width of [illegible] meters or less per 1.2 km of ground distance. Record the number as shown in column III.

8. Average the numbers in column III and record this value at the bottom of the column.

Table 6.7 Gully Summary		
I Line Segment	II No. of Gullies	III No. of Gullies/1.2 km
A-A	9	3.0
B-B	3	1.0
C-C	6	2.0
D-D	12	4.0
E-E	1	0.3
F-F	0	0.0
G-G	3	1.5
H-H	6	3.0
I-I	7	3.5
J-J	1	0.5
K-K	11	5.5
L-L	0	0.0
		Average = 2.0

c. Number and Location of Point Obstacles. The procedure for counting point obstacles differs slightly from that described for the other surface irregularities. Since rarely does a grid line, A-A, B-B, etc., pass directly over point obstacles, they are counted within a 1 [illegible] wide swath along each path. The measurement details follow:

1. Prepare a table as shown in table 6.8 for recording the data.

2. Prepare a working overlay for location of point obstacles.

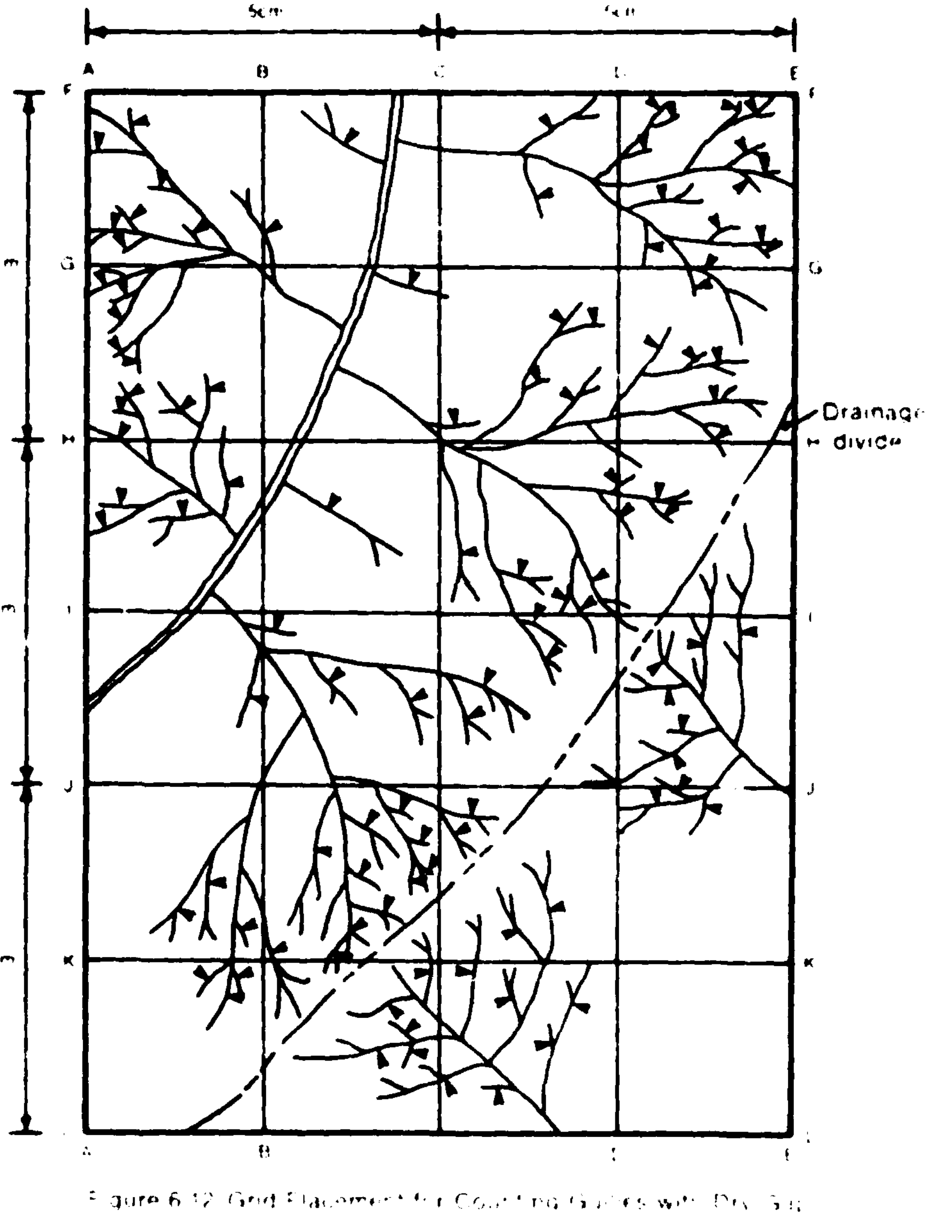


Figure 6.12 Grid Placement for Counting Gullies with Dry [illegible] Widths of 3 Meters or Less

Table 8. Point Obstacle Summary		
Line Segment	# of Point Obstacles	# of Point Obstacles / km
[illegible]	26	8.1
[illegible]	29	9.7
[illegible]	30	[illegible]0
[illegible]	19	9.5
[illegible]	37	8.5
[illegible]	19	9.5
[illegible]	24	12.0
[illegible]	16	8.0
		Average 10.7

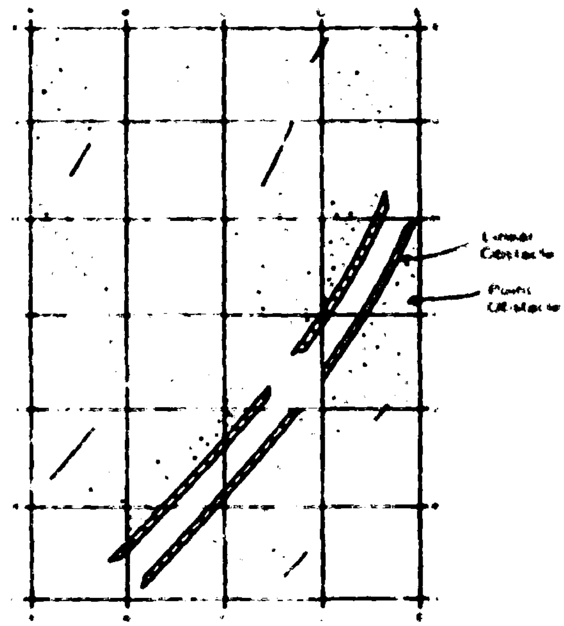


Figure 6.13 Grid Placement for Counting the Number of Linear and Point Obstacles

Table 6.9 Fence Row Summary		
Line Segment	# of Fence Rows	# of Fence Rows / [illegible]
A-A	0	0
B-B	3	1.0
C-C	1	0.3
D-D	2	0.7
E-E	1	0.3
F-F	1	0.3
G-G	3	1.5
H-H	[illegible]	0.5
I-I	0	0
J-J	0	0
K-K	1	0.5
L-L	0	0
		Average = 0.4

[illegible] count the number [illegible] [illegible] subtle, [illegible] changes [illegible].

3. Record these values as shown in [illegible], calculate the average as before, and place the number at the bottom of the column.

Table 6.10 Tone Change Summary

I Line Segment	II # of Tone Changes	III # of Tone Changes / [illegible] km
A-A	20	6.7
B-B	25	[illegible]
C-C	26	[illegible]
D-D	32	10.7
E-E	29	[illegible]
F-F	19	[illegible]
G-G	19	9.0
H-H	20	10.0
[illegible]	21	10.5
[illegible]	16	8.0
[illegible]	17	8.5
[illegible]	18	[illegible]
		Average = 9.0

[illegible] Number and location of linear [illegible]. [illegible] counting linear obstacles is similar [illegible] analysis, i.e., observe and count the [illegible] B-B, etc., intersects with an obstacle.

1. Prepare a table as shown in [illegible].

2. Prepare a working overlay [illegible] linear obstacles.

3. Count the number of linear obstacles [illegible] explained [illegible] record these values as shown in column [illegible] illustrates [illegible] example of grid placement for linear obstacles.

4. Calculate the number of linear obstacles per [illegible] km and record these values in column III.

5. Average the numbers as shown in column III and record this value at the bottom of the column.

[illegible]. Transfer the location [illegible] linear [illegible] of [illegible] dimension [illegible] the working [illegible] the draft [illegible] overlay.

[illegible] segment	# of linear obstacles	# [illegible] obstacles [illegible]
A A	6	[illegible]
B B	[illegible]	[illegible]
C C	2	[illegible]
D D	5	[illegible]
E E	[illegible]	[illegible]
F F	6	6
[illegible]	[illegible]	[illegible]
H H	2	[illegible]
[illegible]	2	[illegible]
J J	5	[illegible]
K K	2	[illegible]
L L	[illegible]	[illegible]
		Average = [illegible]

Table 6-[illegible] [illegible] Obstacle Summary

c. Location of area obstacles.

1. Note the location of all area obstacles [illegible] (these obstacles are not an input to the surface roughness calculation, but rather are simply recorded for inclusion on the surface roughness overlay).

2. Transfer the location of all area obstacles from the working overlay to the draft surface roughness overlay.

6.6 Surface Roughness Index Calculation Examples

Calculation examples using equation [illegible] are [illegible]. The examples include a lakebed form and an interbedded [illegible] form (semi-arid). Calculation [illegible] the lakebed [illegible], but for the rock form, two table top locations [illegible] are calculated separately. The [illegible] sedimentary rock landform with the largest SRI [illegible] for this rock form.

$$SRI = 0.[illegible]\left(\frac{[illegible]}{[illegible]}\right) + [illegible] + [illegible] + [illegible]$$

7. TYPICAL TOPOGRAPHIC GEOLOGIC FORMS

List of Topographic Geologic Forms

7.1 Introduction to Glacial Forms*

Glaciers result when snow and ice, having accumulated to a certain weight, lose their familiar crystalline structure and become plastic. As the accumulation continues, the structure begins to flow outward under its own weight and the destructive process of glaciation is begun. During its progress, the glacier flows with a tremendous mass; it scours, scrapes, and transports soil and rock materials across hundreds of miles, depositing them along the entire extent of its flow. Glacial deposits both influence and disrupt postglacial drainage systems.

Glacial landforms occur from erosion and deposition on the earth's surface as a result of glacial activity. Two types of glaciation occur: alpine glaciation is the result of the actions of valley glaciers and is found in mountainous regions; continental glaciation resulted from glacial activity that affected significant portions of a continent.

Glacial ice is heavily loaded with accumulated rock and soil debris known as glacial drift. Glacial drift refers to all types of debris transported by glacial ice, without any sorting or stratification. Rocks and soil textures are of sizes from erratics to very fine silts and clays. The crushing and grinding of the rock materials creates very fine, uniform, silt-sized particles (rock flour) which have angular, unweathered characteristics. As the ice advanced, then receded and melted, all of these materials were eventually dumped or scattered or sometimes stratified to create a variety of landforms.

Distribution. — Glacial deposits occur over 30 percent of the exposed land surface of the earth. The major glaciated regions are listed in the following paragraphs.

North America (United States and Canada). — Most of the northern third of the United States was glaciated and all regions of Canada have been glaciated.

Central and South America. — Mountain chains occur in Peru and Chile.

Africa. — The African continent has not recorded features of continental glaciation.

Europe. — Most of northern Europe was glaciated, creating till formations covering portions of Norway, Finland, Sweden, the northern British Isles, Denmark, northeastern Germany, northern Poland, and northwestern Russia. Smaller till deposits occur in the Alps and Pyrenees.

Asia. — In Asia, some portions of land were glaciated, including northern Siberia, the central Siberian plateau, New Siberian Island, Wrangel Island, the Koryak Mountains, the Kamchatka Peninsula, the Tian Shan and Altai (?) ... the Himalaya Mountains of central Asia, and the Caucasus Mountains in Asia Minor.

Australia. — Only the western half of Tasmania and a portion of South Island in New Zealand were glaciated, primarily in the form of alpine glaciers.

Pacific and Caribbean Regions. — No significant glacial deposits are found.

The maps on pages 7-4 and 7-5 show the United States and World distribution of Glacial forms.

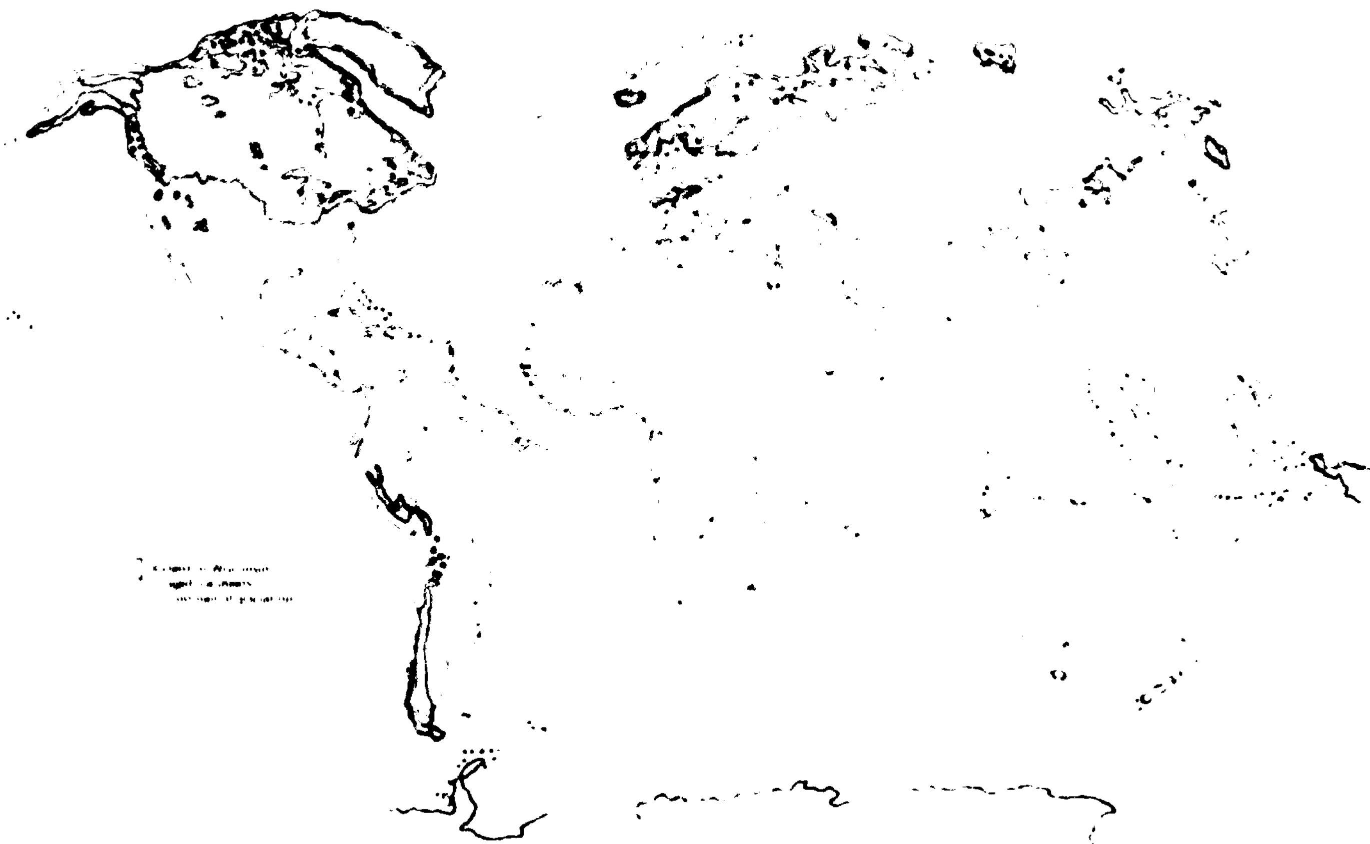
A flow diagram for Glacial forms (7-6) illustrates how the terrain analyst may enter this section to find information on a landform of glacial origin. The diagram may be entered at the top to find a given landform based on origin or entered at the bottom of the diagram when based on form.

Topographic map, air photo, and surface roughness data elements are described for Glacial forms in the following paragraphs. At the end of this section, the results of topographic map and air photo surface roughness measurements are tabulated.

*From Way, D.S., Terrain Analysis, 1978, © Dowden, Hutchinson & Ross, Inc., Stroudsburg, PA.

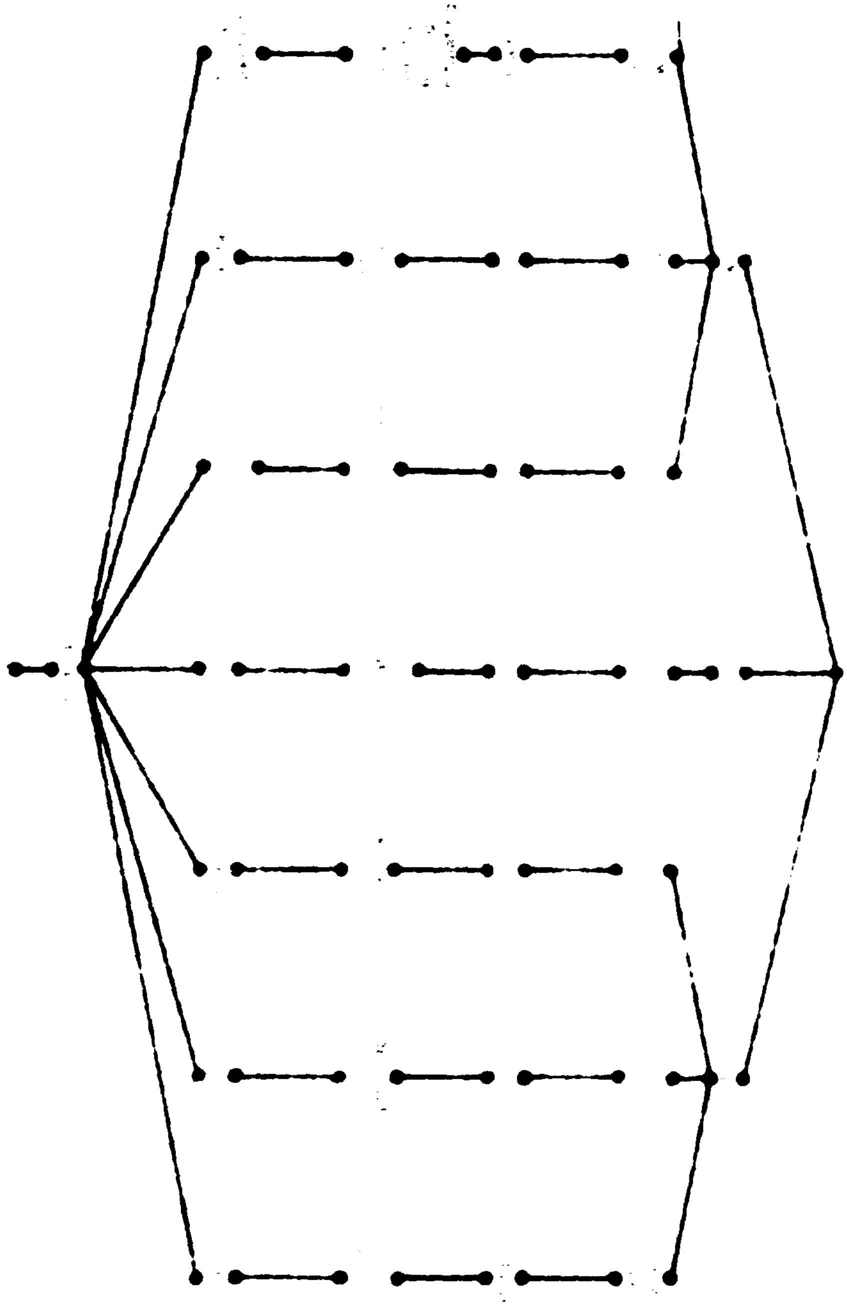
Distribution of Major Groups of Glacial Landforms Across the United States

Source Way D.S. Terrain Analysis 1978 Dowden, Hutchinson & Ross, Inc. Stroudsburg PA p 207

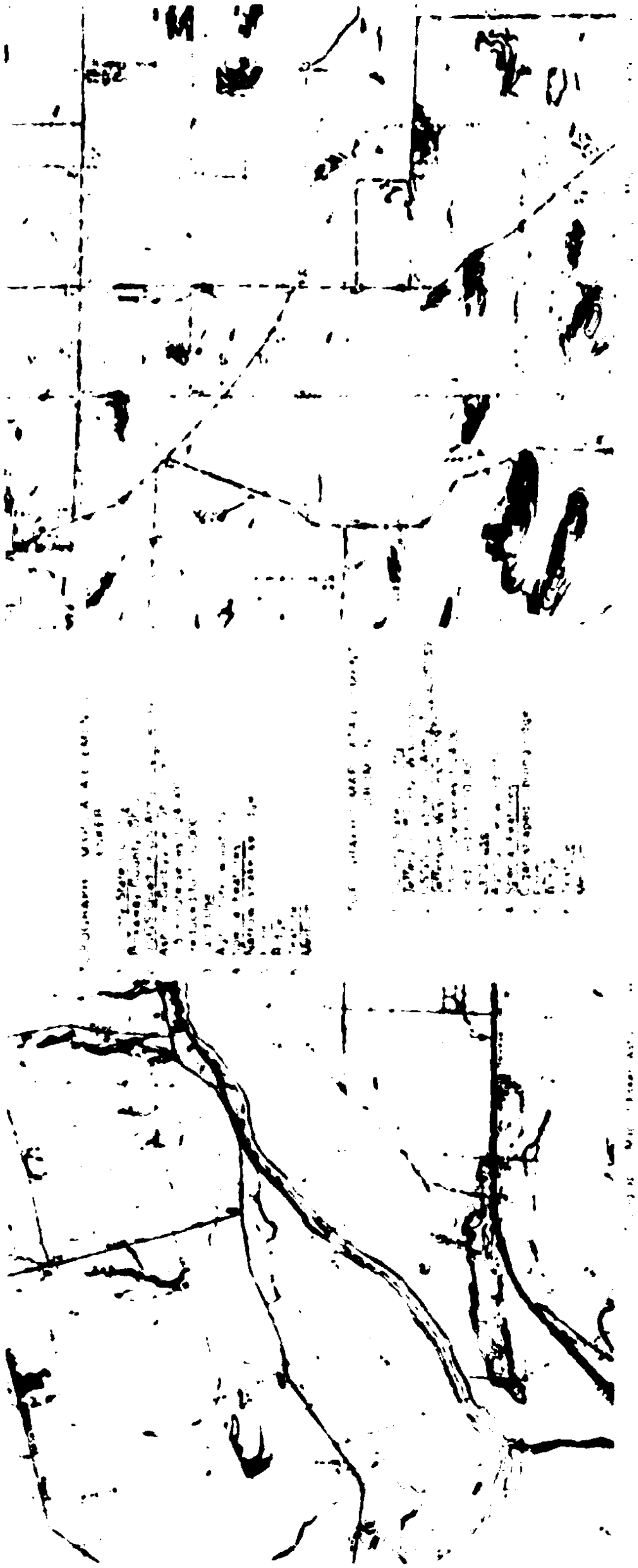


Distribution of Major Groups of Glacial Landforms Around the World

• Source: Way, D.S., Terrain Analysis, 1978, Dowden, Hutchinson & Ross, Inc., Stroudsburg, PA, p. 208



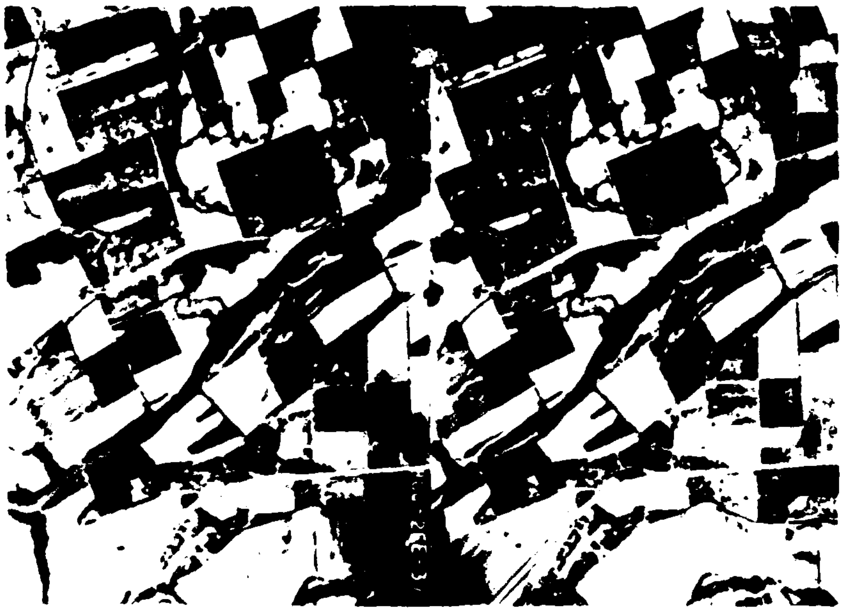
[illegible].1.[illegible] Esker/Drumlin



[illegible] PATTERN DATA ELEMENTS ESKER

[illegible]

ELEMENTS	DESCRIPTORS
[illegible]	Ridge [illegible] shaped
[illegible]	[illegible] pattern surface runoff excellent [illegible] drainage is poor water stands at base of esker and marshy areas form
[illegible]	[illegible] cutting near saddles [illegible] water gaps
[illegible]	[illegible]
[illegible]	Light [illegible]
[illegible]	[illegible] pasture
Vegetation	Natural forest no underbrush forests form cover on areas near base of esker



[illegible] PATTERN DATA ELEMENT [illegible]

[illegible] This area known as the Niagara [illegible]

ELEMENTS	DESCRIPTORS
[illegible]	[illegible]
Drainage	[illegible] drainage excellent [illegible] pattern
[illegible]	[illegible]
Special Features	[illegible] shaped ridges
Color (Photo Gray Tones)	Light on ridge crests where cultivated
Land Use	Cultivated farm land [illegible] granular soils exist
Vegetation	Cleared for agriculture [illegible] in natural forest

7.1.2 Kame-Terrace/Moraine

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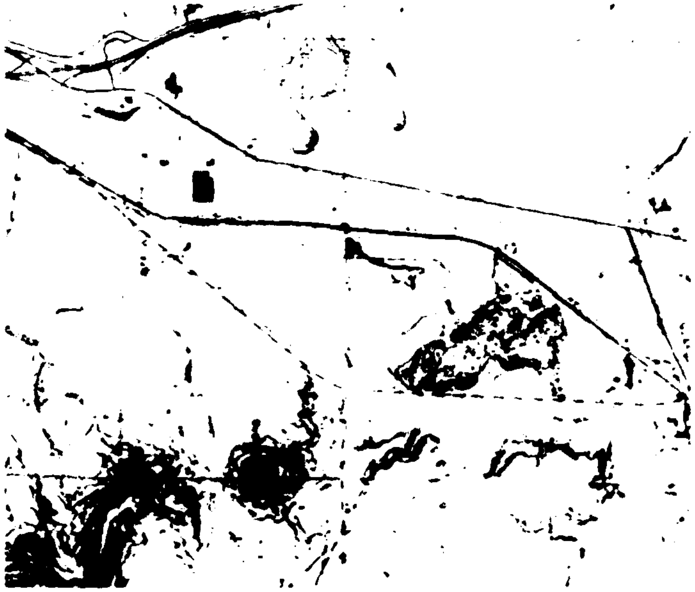
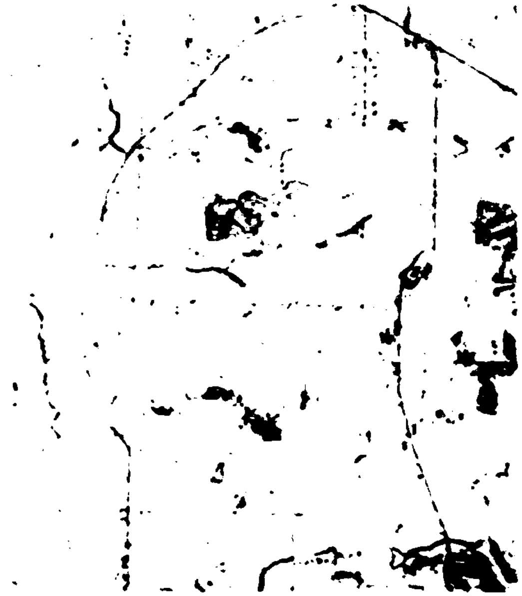


KAME TERRACE

MORAINE



Map of Moraine, Amanda, Ohio

ELEMENTS: MORAINE

Ridges are short with steep sides

Changes associated with

and

agricultural

[illegible]

[illegible]

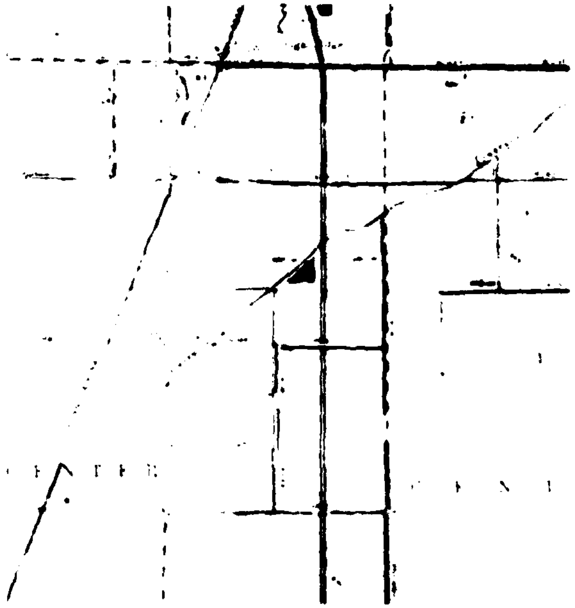
ELEMENTS	DESCRIPTION
Form	[illegible]
Drainage	[illegible]
Local Characteristics	[illegible] appear [illegible] shaped [illegible] present
Special Features	[illegible] shaped mound [illegible] flat plain
Color / Photo Gray Tones	Light on hill crest, uniform gray on terrace
Land Use	Infrequently cultivated [illegible] grazing and pasture [illegible] Flat plain is cultivated
Vegetation	Forests on steep slopes, dense thick undergrowth at base of slopes are swamps or marshes

[illegible]

[illegible]

ELEMENTS	DESCRIPTION
Form	[illegible]
Drainage	Deranged [illegible] medium density [illegible] swamps [illegible]
Local Characteristics	[illegible] saucer shaped [illegible] Erosion is common
Special Features	Rolling terrain and deranged drainage
Color / Photo Gray Tones	Heterogeneous on slope, light where [illegible] eroded depressions are dark
Land Use	Limited agriculture but some crop cultivation, ground water found in local areas, striped field patterns show erosion control
Vegetation	Woodlots and swamps occur, some crop cultivation, ground water available in local areas, orchards found locally

7.1.3 Lakebed Sandy Lakebed



TOPOGRAPHIC MAP DATA ELEMENTS
LAKEBED

1. County, State Country
   Wood County, Ohio
2. USGS Quad or US Army Topo Series
   Bowling Green North Dunbridge Tr...
   1971
   7.5 minute series 1:24,000
   (reduced to 1:50,000)
3. Land Use
   Agriculture, woodlots, quarries
4. Special Features
   Flat topography
5. Form
   Plain
6. Texture
   Coarse

TOPOGRAPHIC MAP DATA ELEMENTS
SANDY LAKEBED

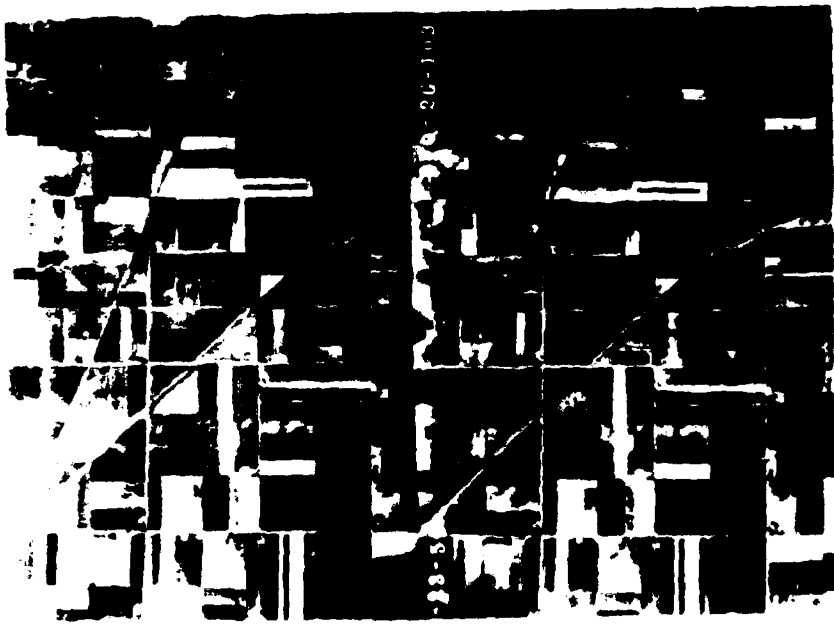
1. County, State Country
   Racine Kenosha County, Wisconsin
2. USGS Quad or US Army Topo Series
   Racine South, Wisconsin
   7.5 minute series 1:24,000
   (reduced to 1:50,000)
3. Land Use
4. Special Features
5. Form
6. Texture

[illegible]

Element	Description
[illegible]	[illegible]
[illegible]	[illegible] water table [illegible]
[illegible]	[illegible] saucer shaped [illegible] present
Special features	Large field patterns of uniform gray tone bordered by beach ridges
Photo gray tones	Varies with soil texture, usually uniform [illegible] gray [illegible] wet zones where beach ridges [illegible] light toned, sandy
Land use	Specialized crops, meadowland, dairy herds
Vegetation	Cleared for cultivation, specialized crops, meadowland, shallow swamps

[illegible]

Element	Description
[illegible]	[illegible]
Drainage	[illegible]
[illegible]	[illegible] present
Special features	[illegible]
[illegible]	[illegible]
Land use	[illegible]
Vegetation	[illegible]



[illegible].1.4 Outw[illegible]

TOPOGRAPHIC MAP DATA ELEMENTS

[illegible]

Results of Topographic Map Surface Roughness Measurements: Glacial Forms

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]		[illegible]	[illegible]	[illegible]			
[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

Results of Air Photo Surface Roughness Measurements: Glacial Forms

[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]						
[illegible]	[illegible]			[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	
[illegible]							
[illegible]				[illegible]			
[illegible]	[illegible]	[illegible]			[illegible]		[illegible]
[illegible]	[illegible]		[illegible]				

[illegible] 1.5 Summary of Surface Roughness Measurements [illegible] Forms

Form	Measurement Method			Average	SRI*
	Empirical	Air Photo	Topographic Map		
Moraine	[illegible]	4.6	[illegible]	[illegible]	4
[illegible]	[illegible]	[illegible]		[illegible]	2
[illegible]	[illegible]	[illegible]	[illegible]		
Kame and Terrace		[illegible]	[illegible]	[illegible]	[illegible]
Outwash Plain	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
[illegible], Lakebed	[illegible]	[illegible]	[illegible]		[illegible]

*Note: See Section [illegible] for explanation [illegible]

2 Introduction to Fluvial Forms*

[illegible] materials are [illegible] throughout the world [illegible] processes are [illegible] weathered [illegible] eroded [illegible] and exposed and become part of the earth's land surface [illegible] consolidated sands with some silts and clays [illegible] unconsolidated sands and gravel which [illegible] There are several types [illegible] according to the predominate composition such as sand flats [illegible] flats and [illegible]

The formation of streams is initiated when either of two conditions [illegible] absorbs the water until it is saturated and (2) rainfall takes place faster than it can be absorbed [illegible] causes the formation of puddles in small depressions. When [illegible] swales between the puddles and the basic lines of an integrated [illegible] system [illegible] Eventually the flowing water begins to have velocities high enough [illegible] carry particles of soil initiating the establishment of [illegible] and stream beds.

Distribution. — Because most landforms and regions are subject to the erosion and deposition of sediments from runoff, fluvial landforms are found in all parts of the world. The following paragraphs [illegible] some occurrences of fluvial formations.

North America, United States and Canada. — Many large rivers in the United States form [illegible] plains; examples are the Mississippi, the Missouri, the Ohio and the Connecticut. The better known delta deposits include the Mississippi River, the Colorado River, and the Saint Clair River deltas.

Most of the fluvial landforms in Canada are flood plains, lake beds, and organic deposits. The MacKenzie River system is the largest, draining most of west central Canada and ending in a [illegible] delta in the Northwest Territories.

South and Central America. — The Amazon River and the Parana River are the major drainage systems of South America. Major deltas are found at the mouth of the Amazon in Brazil and the Orinoco in Venezuela. Alluvial formations are found along the base of the Andes.

Africa. — Major river systems include the Nile, Zambezi, Congo, and Niger Rivers. Large deltas are found at the mouths of the Nile and Niger Rivers. Extensive portions of Africa are covered with [illegible] deposits.

Europe. — There are many river systems in Europe, including the Rhine, the Danube, and [illegible] eastern Russia. The Danube and Volga Rivers have developed large deltas.

Marine formations are found from the Netherlands east to Poland with some [illegible] along the northern coast of eastern Russia.

Asia. — Many large river systems are found in Asia: the Hwang Ho and Yangtze Kiang in China, the Mekong in southeast Asia, and the Ganges in India. Major deltas include those found at the mouths of the Lena and Indigirka Rivers in Russia, the Indus River in Pakistan, the Cauvery, Godavari, and Mahanadi Rivers in India.

Australia. — Numerous stream systems, including the Murray River, contain fluvial forms.

Pacific and Caribbean Regions. — Local marine formations are the predominate fluvial landforms.

The maps on pages 7-26 and 7-27 show the United States and World distribution of Fluvial forms.

A flow diagram for Fluvial forms (7-28) illustrates how the terrain analyst may enter this section to develop information on a landform of fluvial origin. The diagram may be entered at the top to find a given landform based on origin or entered at the bottom of the diagram when based on form.

Topographic map, air photo, and surface roughness data elements are described for Fluvial forms in the following paragraphs. At the end of this section, the results of topographic map and air photo surface roughness measurements are tabulated.

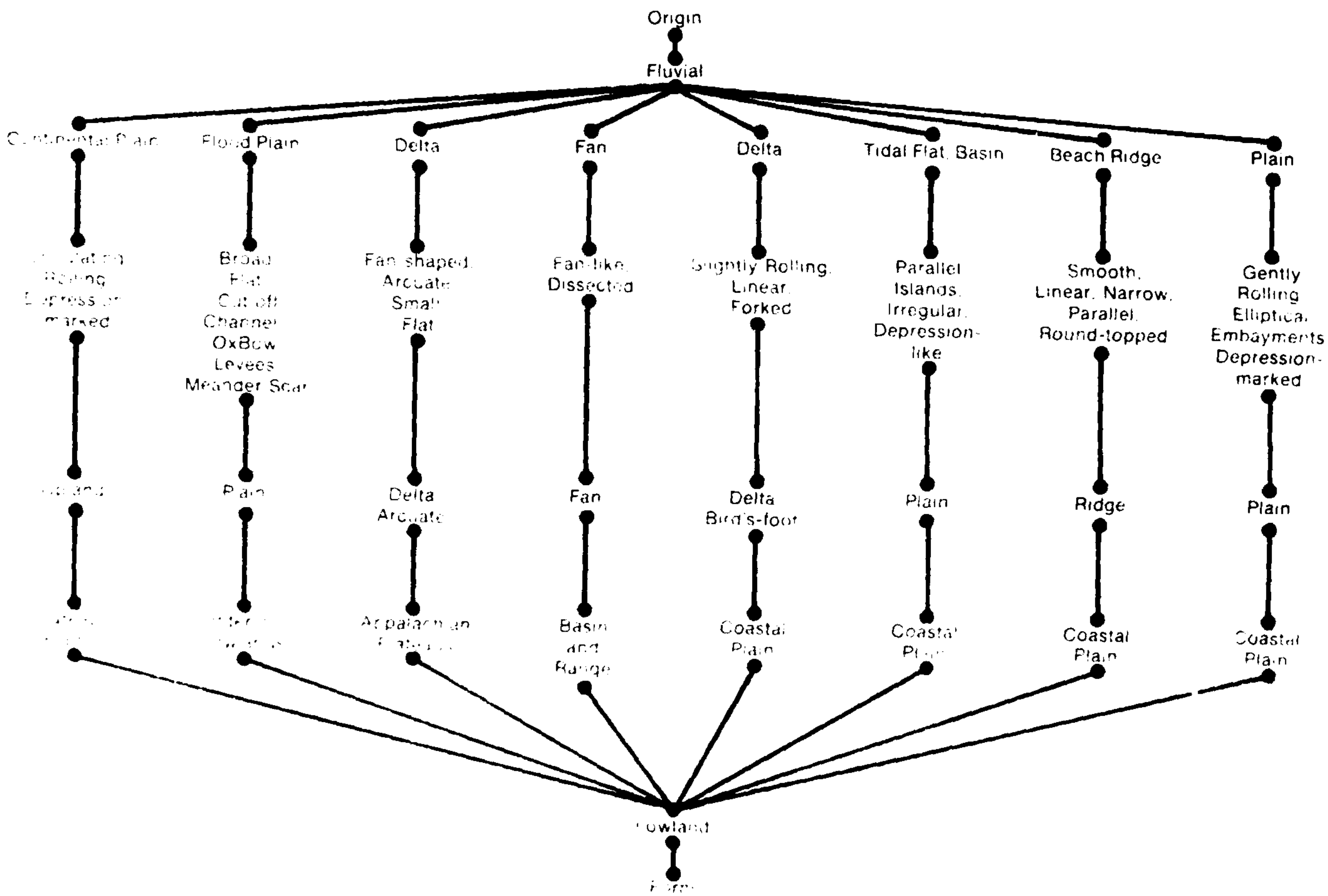
*From Way, D.S., Terrain Analysis, 1978. © Dowden, Hutchinson & Ross, Inc. Stroudsburg, PA

Distribution of Fluvial Forms Throughout the United States. Note That Swampy Areas Indicate Only 10-50% Coverage by Actual Swamps

Source: Way, D.S., Terrain Analysis, 1978, © Dowden, Hutchinson & Ross, Inc., Stroudsburg, PA p. 293

Distribution of Fluvial Landforms Throughout the World.

Source: Way, D.S., Terrain Analysis, 1978, © Dowden, Hutchinson & Ross, Inc., Stroudsburg, PA, p. 294



This Flow Diagram is Used to Determine the Relationship of Origin to Form for Each of the Fluvial Landforms Illustrated in Section 7

7.2.1 Coastal Plain/Continental Plain

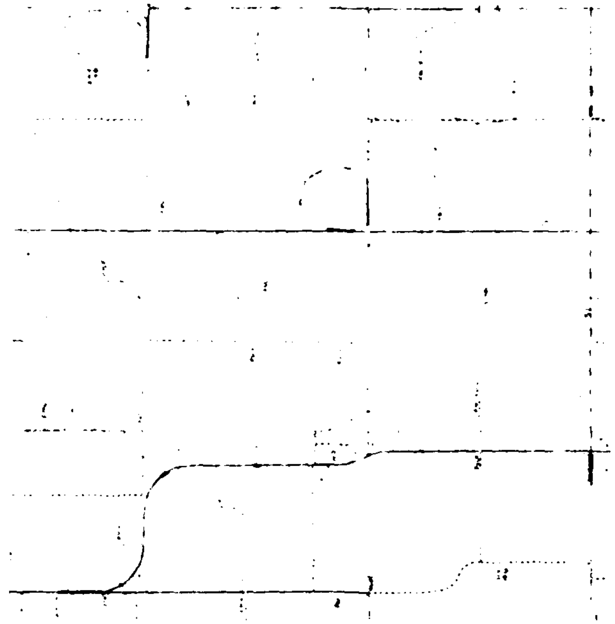
Topographic Map of [illegible] Coastal Plain [illegible]

TOPOGRAPHIC MAP DATA ELEMENTS
COASTAL PLAIN

1. County/State/Country
   Marion County, South Carolina
2. USGS Quad or US Army Topo Series
   Mullins, South Carolina (1946)
   1:24,000
   (reduced to 1:50,000)
3. Land Use
   Marsh, natural cover
4. Special Features
   Marshes, circular
5. Form
   Plain
6. Texture
   Coarse

TOPOGRAPHIC MAP DATA ELEMENTS
CONTINENTAL PLAIN

1. County/State/Country
   Crosby County, Texas
2. USGS Quad or US Army Topo Series
   Ralls NE Crosbyton, Texas (1966)
   7.5 minute series   1:24,000
   (reduced to 1:50,000)
3. Land Use
   Agriculture, oil gas wells
4. Special Features
   Depressions (Buffalo wallows)
5. Form
   Upland with multiple depressions
6. Texture
   Coarse



Topographic Map of Continental Plain [illegible] Tx

SURFACE ROUGHNESS DATA ELEMENTS COASTAL PLAIN

Irregularities	[illegible]
Form	[illegible]
Drainage	[illegible] coarse
[illegible]	[illegible]
[illegible]	[illegible] dark
[illegible]	[illegible]
[illegible]	[illegible] drainage
[illegible]	[illegible]
[illegible]	[illegible]

SURFACE ROUGHNESS DATA ELEMENTS CONTINENTAL PLAIN

Irregularities	SRI 1 Very smooth, no irregularities
Form	Flat, smooth
Drainage	Wet [illegible] depressions [illegible]
Gully Characteristics	U-shaped to saucer shaped [illegible]
Tone (photo gray tones)	Uniform photo gray tones
Land Use	Cultivated [illegible]
Vegetation	Sparse
[illegible]	[illegible]
Relief	Low
[illegible]	[illegible]

PHOTO PATTERN DATA ELEMENTS: COASTAL PLAIN
Photos ASP 1 - 247, 248 - 1968
Physiography

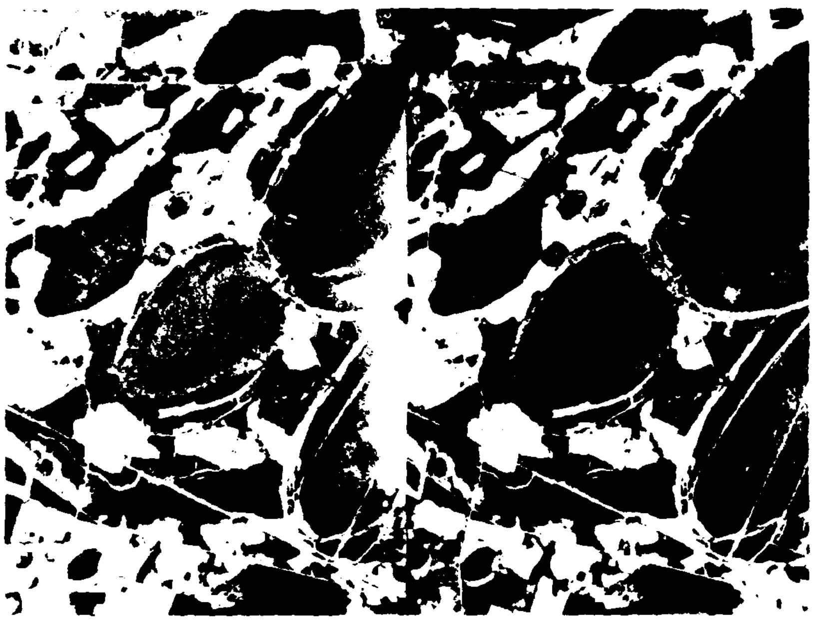
The Coastal Plain - The coastal plain is a simple nearly flat structure consisting of unconsolidated layers of marl, sand, silt and clay recently elevated above the ocean floor. From the Piedmont the plain grades easterly imperceptibly to the coast where low level formations such as estuaries and tropical bays are found. (Wet, Subtropic)

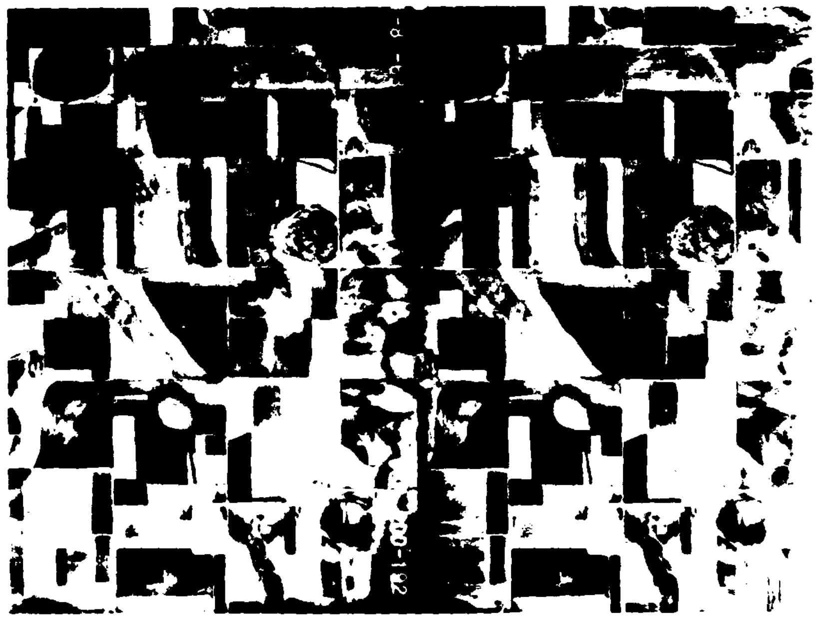
ELEMENTS	DESCRIPTORS
Form	Plain, gently rolling, undulating topography, irregular surfaces in upland areas
Drainage	Parallel to coarse dendritic
Gully Characteristics	Soft U shaped
Special Features	U shaped gullies, elongated oval shaped depressions, contour farming
Color (Photo Gray Tones)	Light and dark, light in upland cultivated areas, dark in depressions, gullies and drainageways
Land Use	Lowland and depressions - swamps, forest; Upper uplands - contour plowing, crops, cotton, tobacco
Vegetation	Dense forest occurs in lowland areas with depressions usually forming swamps. Upland areas are cultivated with irregular field patterns

PHOTO PATTERN DATA ELEMENT: CONTINENTAL PLAIN
Photos CGF, 200-191, 192 - 1963
Physiography

The Great Plains - The High Plains section, a long broad synclinal interrupted by uplifts, is located on the eastern edge of the Southern Rockies. It is a rolling plain (basin) consisting of sediments from the eastward flowing streams exiting the Front Range. These uplands have irregular surfaces subject to strong wind erosion. Dust Bowls (circular forms) occur in scattered locations. (Semi-arid)

ELEMENTS	DESCRIPTORS
Form	Upland, a very flat plain with many shallow depressions
Drainage	Young streams meander across without developing significant patterns in granular materials
Gully Characteristics	Saucer shaped where developed inland, but at valley walls U shaped gullies predominate
Special Features	Buffalo wallows
Color (Photo Gray Tones)	Light to medium gray tones, except dark in poorly drained areas where moisture can collect such as in buffalo wallows
Land Use	Farming, alternate field patterns
Vegetation	Grassy plains





7.2.2. Tidal Flat Basin/Beach Ridge

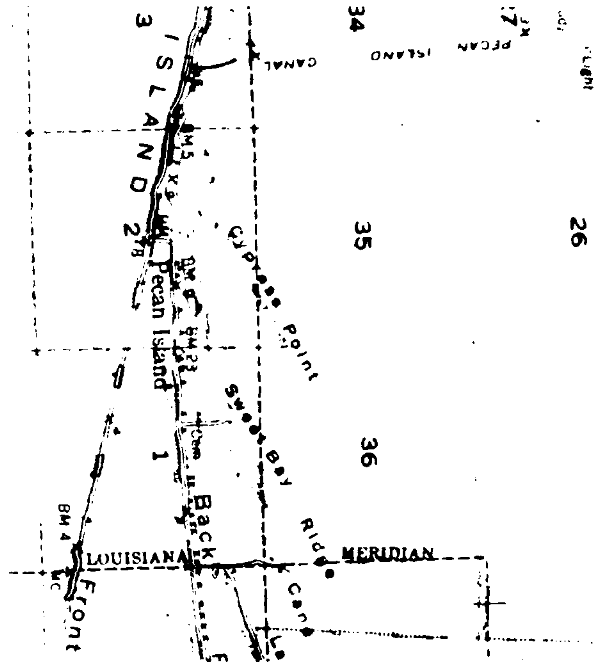
Map ... Legarsville Kiawah

TOPOGRAPHIC MAP DATA ELEMENTS
TIDAL FLAT (BASIN)

1. County, State Country
Charleston County, S. Carolina
2. USGS Quad or US Army Topo Series
Legarsville Kiawah Island, S. Carolina (1971)
7.5 minute series 1:24,000 (reduced to 1:50,000)
3. Land Use
... cover
4. Special Features
... of water storage
5. Form
Plain
6. Texture
Coarse

TOPOGRAPHIC MAP DATA ELEMENTS
BEACH RIDGE

1. County, State Country
Vermillion Parish, Louisiana
2. USGS Quad or US Army Topo ...
Pecan Island, Louisiana (1951)
15 minute series 1:50,000
3. Land Use
Wooded, natural cover
4. Special Features
Linear, narrow ridges
5. Form
Ridges, beach
6. Texture
Coarse



Topographic Map of Beach Ridge, Pecan Is., LA

... ELEMENTS TIDAL FLAT BASIN

SURFACE ROUGHNESS DATA ELEMENTS: BEACH RIDGE

Irregularities	SR ... Many small irregularities
Form	Narrow, low, elongated ridges ... parallel to each other and to the shore ... have a banded appearance ... tops are flat
Drainage	Wet ground and swamps occur between ridges. Mostly internal on ridge
Gully Characteristics	Gullies cut through ridges
Color (Photo Gray Tones)	Ridges are light gray in tone with dark depressions, light and mottled in low cultivated sandy areas
Land Use	Dwellings and roads on ridge tops
Vegetation	Trees occur on ridge tops
Soil Rock	Sand
Relief	Low
Slope	Gentle

PHOTO PATTERN DATA ELEMENTS: TIDAL FLAT BASIN

[illegible]

DISCUSSION

[illegible]

ELEMENTS	DESCRIPTORS
Form	[illegible]
Drainage	Dendritic pattern, meandering streams, [illegible] features
Gully Characteristics	Not developed
Special Features	Broad meandering dendritic systems of drainage
Color (Photographic Tones)	Organic depressions are dark, may occur where vegetation covered or in blocked drainage ways; usually gray in mud flats
Land Use	Where [illegible] and drained, intensive agriculture [illegible]; elsewhere usually wildlife refuges
Vegetation	Marsh grasses

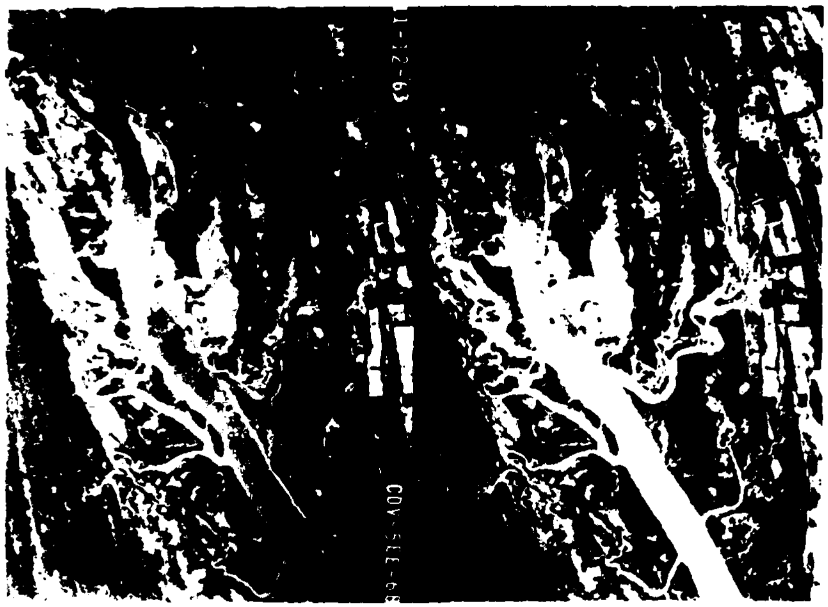
PHOTO PATTERN DATA ELEMENTS: [illegible]

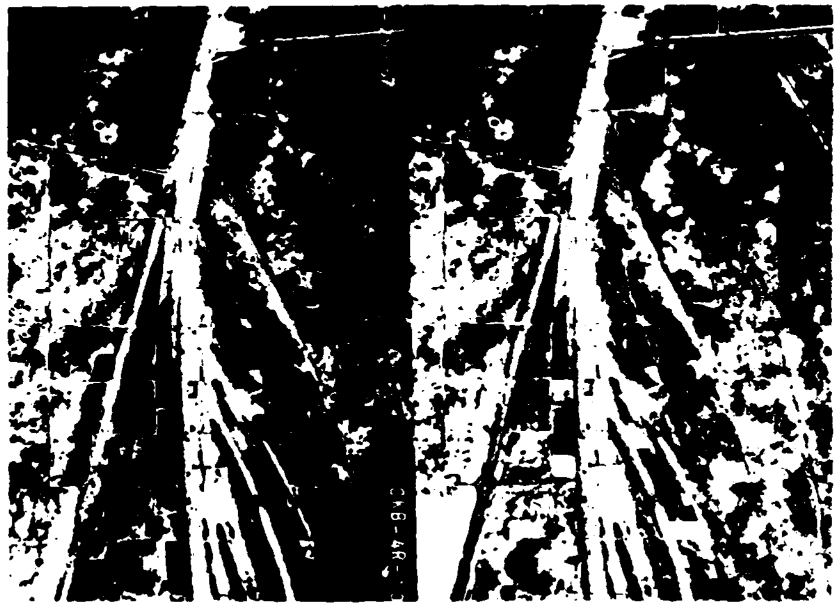
[illegible]

DISCUSSION

[illegible]

ELEMENTS	DESCRIPTORS
Form	Plain, narrow, parallel raised features a few feet [illegible] along coast [illegible]
Drainage	[illegible]
Gully Characteristics	[illegible]
Special Features	[illegible] organic matter
Color (Photographic Tones)	Light tones where cultivated [illegible]; dark when tree covered or marsh [illegible]
Land Use	Some quarrying [illegible] material along coast; cultivated [illegible] crops
Vegetation	Pine forest [illegible] cultivated





7.2.3 Delta, Bird's-foot Delta, [illegible]

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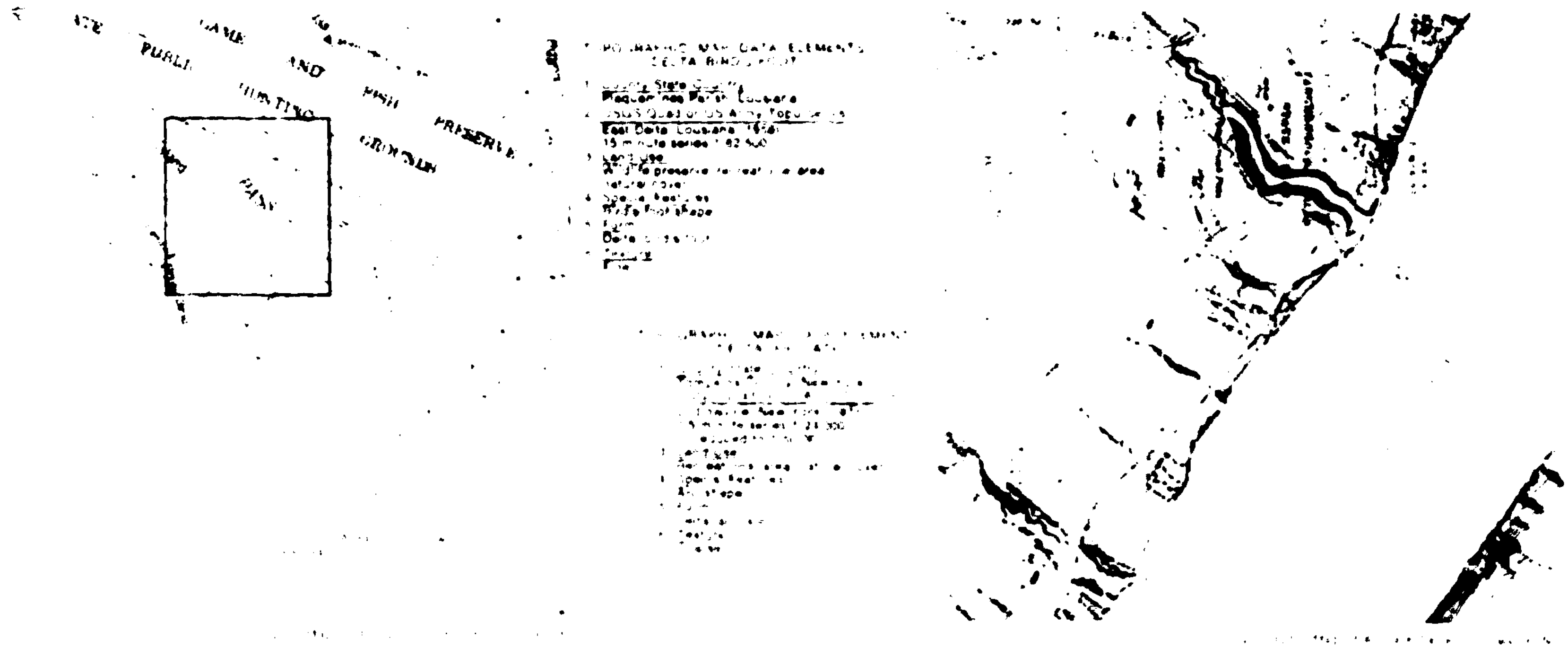

GAME
AND
FISH
PRESERVE
GROUNDS
DATA ELEMENTS
East Delta, Louisiana
15 minute series

PHOTO PATTERN DATA ELEMENTS: DELTA, BIRD'S FOOT

Photos: Stereogram [illegible]

Physiography:

The Coastal Plain. [illegible] the Mississippi River [illegible] New Orleans [illegible]

ELEMENTS	DESCRIPTION
Form	[illegible] shaped [illegible] fan shaped [illegible] downstream [illegible] body of water adjacent
Drainage	[illegible] shaped [illegible] downstream [illegible]
[illegible]	None [illegible]
Special Features	[illegible] shaped [illegible] materials and drainage
[illegible]	[illegible]
Photo [illegible]	
Land Use	[illegible]
Vegetation	Marsh [illegible]

PHOTO PATTERN DATA ELEMENTS: DELTA, ARCUATE

Photo: [illegible]

Physiography:

The Appalachian Plateau. [illegible] arcuate delta [illegible]

ELEMENTS	DESCRIPTION
Form	Delta, Arcuate [illegible] fan shaped [illegible] surface
Drainage	[illegible] delta [illegible]
[illegible]	[illegible] water
Special Features	[illegible]
[illegible]	Light to medium gray [illegible] delta
Photo [illegible]	
Land Use	Recreational [illegible]
Vegetation	[illegible]

Stereopair of Bird's Foot Delta

Stereopair of Arcuate Delta

7.2.4 Alluvial Fan Floodplain

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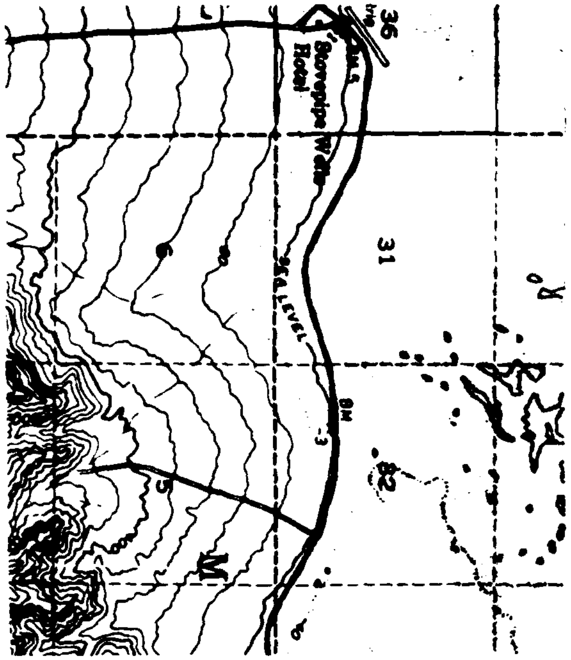


Topographic Map of Alluvial Fans Stovepipe Wells CA

TOPOGRAPHIC MAP DATA ELEMENTS ALLUVIAL FAN

1. County State Country
   Inyo County California
2. USGS Quad or US Army Topo Series
   Stovepipe Wells California (1952
   15 minute series 1 62 500
   (enlarged to 1 50 000)
3. Land Use
   Natural cover barren
4. Special Features
   Fan shape
5. Form
   Fan
6. Texture
   Coarse

TOPOGRAPHIC MAP DATA ELEMENTS FLOOD PLAIN TERRACE

1. County State Country
   Coshocton County Ohio
2. USGS Quad or US Army Topo Series
   Fresno Ohio (1978
   7.5 minute series 1 24 000
   (reduced to 1 50 000)
3. Land Use
   Agriculture woodlots natural cover
4. Special Features
   Cutoffs oxbows meandering streams
5. Form
   Plain
6. Texture
   Coarse

Topographic Map of Flood Plain Terrace Fresno OH

SURFACE ROUGHNESS DATA ELEMENTS ALLUVIAL FAN

Irregularities	SRI 3 Many small irregularities
Form	Ripples located transverse to flow rugged topography cross-fan transverse to flow
Drainage	Small channels located transverse to flow
Gully Characteristics	Many longitudinal gullies dissected surface
Color (Photo Gray Tones)	Light photo gray tones
Vegetation	Scrub growth
Soil Rock	Larger sized debris (boulders) near apex finer materials downfan
Relief	Moderate
Slope	8% downslope angle steeper slope at apex of fan where materials empty into valley and along the margin of the fan

SURFACE ROUGHNESS DATA ELEMENTS FLOOD PLAIN TERRACE

Irregularities	SRI 2 Few small irregularities
Form	Oxbow lake old meander channels channel scars point bars natural levee along large streams
Drainage	Old meander channels wet depression
Gully Characteristics	Few short U shaped to saucer shaped gullies
Color (Photo Gray Tones)	Light to medium gray
Land Use	Agriculture (cultivated) on floodplain agricultural and residential areas on terrace fences fence rows scattered trees and woodlots
Vegetation	Scattered trees and woodlots
Soil Rock	Poorly drained plastic silt clay soils in lowland
Relief	Slight relief change at flood plain terrace boundary
Slope	Gentle

PHOTO PATTERN DATA ELEMENTS ALLUVIAL FAN

Photos IF-1-40 41 (1948)

Physiography

The Basin and Range Province -- This desert region is an area characterized by block-faulted mountains and adjacent basins some below sea level Sediments flow off the tilted blocks and form sloping layered deposits of coarse-to-fine alluvium Erosion causes troughts to form in the surface of these layered deposits (Arid)

ELEMENTS	DESCRIPTORS
Form	Fan series of fan-shaped deposits sloping to a valley along a mountain front The materials grade from gravel to sand to silt downslope
Drainage	Dendritic where developed -- drainage absent on most deposits
Gully Characteristics	Sharp V-shaped gullies with steep gradients
Special Features	Coalescing fans form almost continuous sloping surface
Color (Photo Gray Tones)	Light grays indicate sorted granular materials Dark pattern due to vegetation
Land Use	Agriculture developed on the porous fans Wind erosion occurs if vegetation does not anchor the soil
Vegetation	Plants are restricted to areas containing porous materials which have groundwater

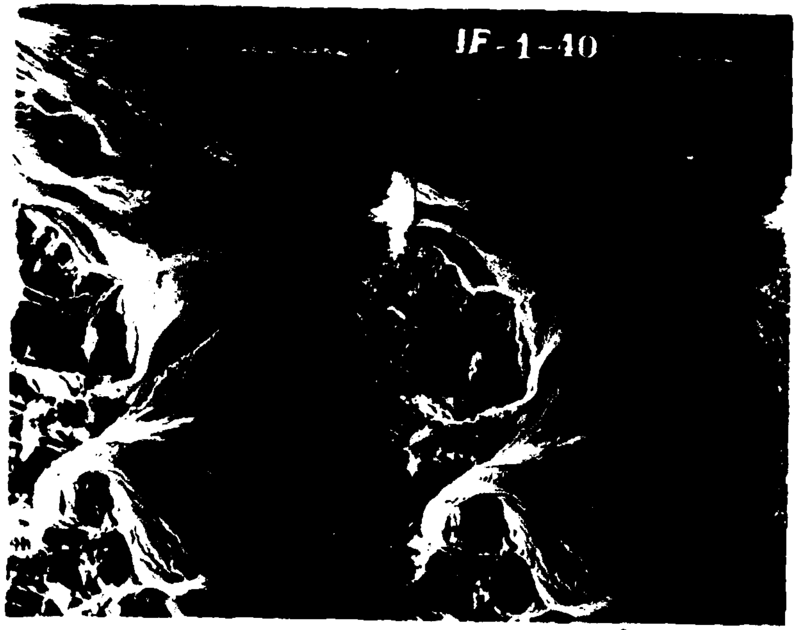
PHOTO PATTERN DATA ELEMENTS FLOOD PLAIN TERRACE

Photos CLT 6FF 14 15 (1965)

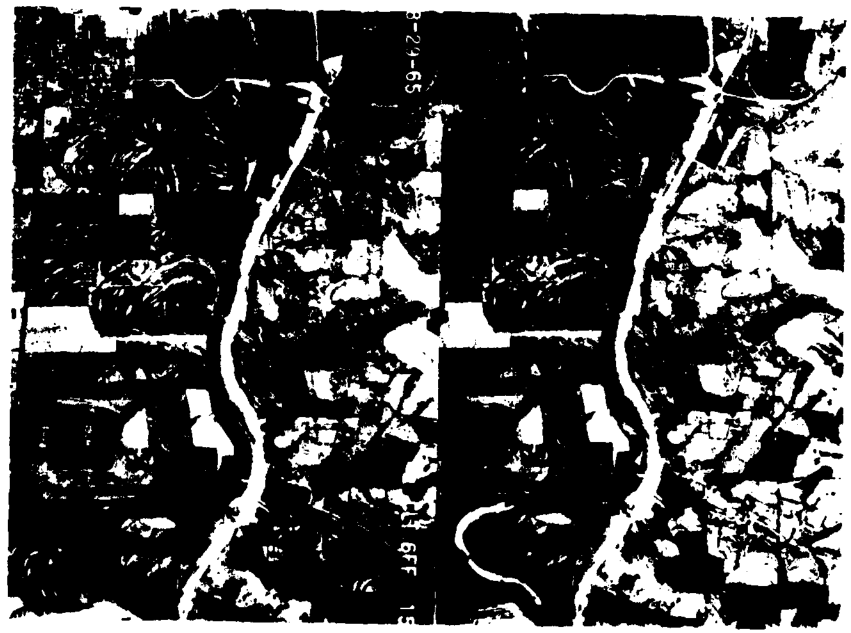
Physiography

The Interior Lowlands - The plains of this lowland are formed in large stream valleys where the Interior Lowlands is joined to the east by the Appalachian Plateau The stream noted in photo flows easterly into the Ohio Basin This broad river valley is characterized by level plains ridges and belts of small hills the alluvial plains have terraces or ridge-like uplands surrounding them (Humid)

ELEMENTS	DESCRIPTORS
Form	Plain broad flat terrace is level bench-like bordered by rolling uplands
Drainage	Abandoned channels and few meandering tributaries internal on benches
Gully Characteristics	Short U-shaped to saucer-shaped V-shaped on benches
Special Features	Oxbow lakes channel scars meander channels point bars natural levees in floodplain
Color (Photo Gray Tones)	Light gray on terrace dark on channel scars and meander channels of floodplain
Land Use	Agriculture on floodplain agriculture and residential on terrace
Vegetation	Scattered trees along levees channels and terrace face



Stereopair of Alluvial Fans



Stereopair of Flood Plain Terrace

Results of [illegible] Map Surface Roughness Measurements: Fluvial Forms

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	N A
[illegible]	[illegible]	[illegible]	[illegible]	0.41	[illegible]	N A	N A	N A
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	N A	N A	N A
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	N A	N A	N A
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Results of Air Photo Surface Roughness Measurements: Fluvial Forms

Data / Form	Flood Plain (and Terraces)	Alluvial Fan	Continental Plain	Tidal Flat	Coastal Plain	Beach Ridges	Delta (Birds Foot)	Delta (Arc)
Gully Frequency (No./5 cm)	[illegible]	[illegible]	[illegible]	6.9	[illegible]	[illegible]	[illegible]	1.0
Contour Bends (No./5 cm)	[illegible]	[illegible]	[illegible]	2.5	1.9	[illegible]	5.3	2.0
Fencerow Frequency (No./5 cm)	[illegible] (8.9)	0	3.0	0	1.7	[illegible]	0	[illegible]
Point Obstacles (No./5 cm)	[illegible]	[illegible]	[illegible]	10.7	0	[illegible]	[illegible]	[illegible]
Linear Obstacles (No./5 cm)	[illegible]	0.6	0	0	0	0	[illegible]	0
Total Changes (No./5 cm)	8.8 ([illegible])	[illegible]	6.8	10.6	16.5	[illegible]	[illegible]	[illegible]
Calculated SRI	2.2 (2.4)	[illegible]	1.7	4.7	3.9	4.8	3.2	2.6

7.2.5 Summary of Surface Roughness Measurements Fluvial Forms

Form	Measurement Method			Average	SRI*
	Empirical	Air Photo	Topographic Map		
Flood Plain and (Terrace)	2	2.2	1.3	1.6	2
Alluvial Fan	4	3.5	2.2	3.2	3
Continental Plain	2	1.7	0.6	1.4	1
Tidal Flat	4	4.[illegible]	1.5	3.4	3
Coastal Plain	3	3.9	3.0	3.3	3
Beach Ridges	2	4.8	2	2.9	3
Delta (Bird's-foot)	3	3.2	2	2.7	3
Delta (Arc)	2	2.6	1	1.9	2

*Note See Section 6 for explanation of method for deriving SRI values

7.3 Introduction to Eolian Forms*

The effects of the transportation of soil grains by eolian (wind) action are very similar to those of the transportation of materials by stream (fluvial) action. Eolian transported particles are carried to the atmosphere, either close to the surface of the ground in a fashion similar to stream bedloads, or higher above the surface of the ground in a fashion similar to suspended stream loads. The lower layer consists of sands which scatter and bounce along the surface, perhaps never rising more than four feet. The upper layer, or suspended load, contains fine-grained, silt-sized particles which are carried for great distances at high altitudes.

Eolian deposits include (1) sand dunes, which occur near the source of the material, and (2) loess, or silt deposits, which are often carried great distances by the wind covering large areas.

Distribution — Eolian landforms occur widely through all parts of the world, but are especially common adjacent to glaciation zones and large flood plains, in arid climates, and along coastal areas.

North America, United States and Canada — Belts of sand dunes are found along the coasts of the Atlantic and Pacific Oceans and the Great Lakes. Extensive inland dune formations are found in the Great Basin in Nevada and in the deserts of southern California. Loess deposits are found adjacent to the large rivers of the Mississippi Valley and cover significant portions of Iowa, Illinois, northern Missouri, southwestern Wisconsin, western Tennessee, western Mississippi, and others.

Sand dune deposits in Canada are few and scattered. Loess is found in small, localized deposits through southern Saskatchewan.

South and Central America — Sand dune formations occur in the central basins of Peru and Chile. Extensive deposits of loess cover most of northern Argentina, southern Uruguay, and southern Paraguay.

Africa — Extensive areas in Africa are covered with sand dunes. Loess cover is found along the coastal sections of Morocco, Algeria, Libya, and the United Arab Republic. Scattered small deposits occur across north central Africa from Senegal to Ethiopia.

Europe — Sand dunes are dominant features along the French coast of the Bay of Biscay, and the coasts of Belgium, the Netherlands, Denmark, and eastern Russia along the Baltic Sea. Dune formations also occur along the major rivers in southern France, Spain, and southern Russia north of the Black Sea.

Asia — Sand dunes occur in many areas of Asia, including Mongolia to northern India, the Gobi Desert, the region from Syria through Iran, and most of Saudi Arabia.

Major deposits of loess are found throughout the Hwang-Ho River Valley in China and along the northeastern edge of the Caspian Sea.

Australia — Much of central Australia contains sand dune formations, including the Great Sandy, Gibson, Great Victoria, Tanami, and Simpson Deserts.

Thin loess deposits cover the central portion of Australia. Thicker deposits occur along the southeastern coast of South Island, New Zealand.

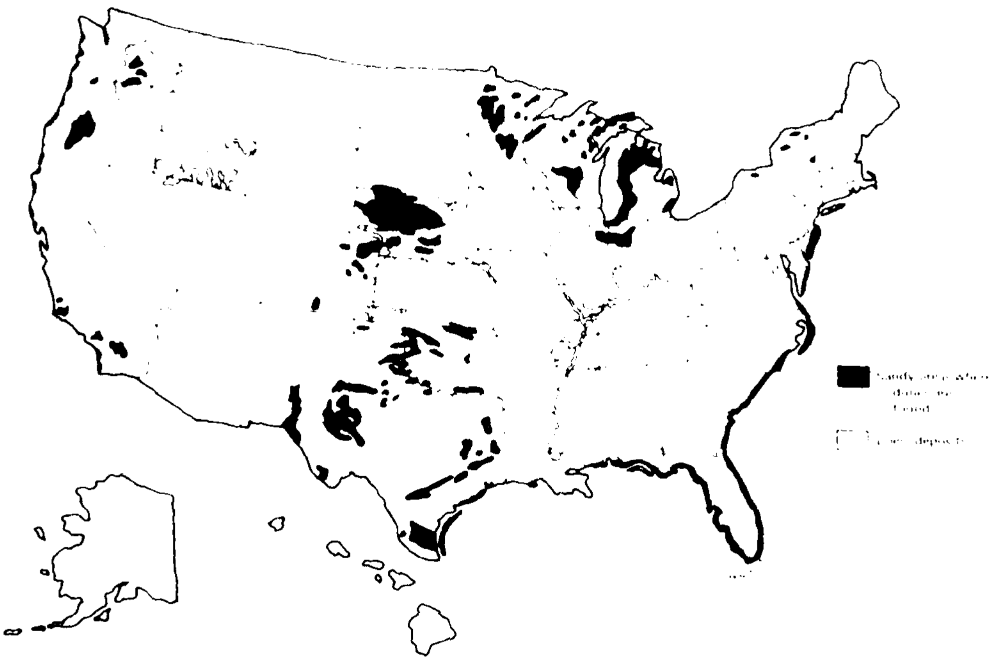
Pacific and Caribbean Regions — Small, calcareous sand dunes of local origin are scattered through the regions. No significant deposits of loess are found.

The maps on pages 7-48 and 7-49 show the United States and World distribution of Eolian forms.

A flow diagram for Eolian forms (7-50) illustrates how the terrain analyst may enter this section to develop information on a landform of eolian origin. The diagram may be entered at the top to find a given landform based on origin or entered at the bottom of the diagram when based on form.

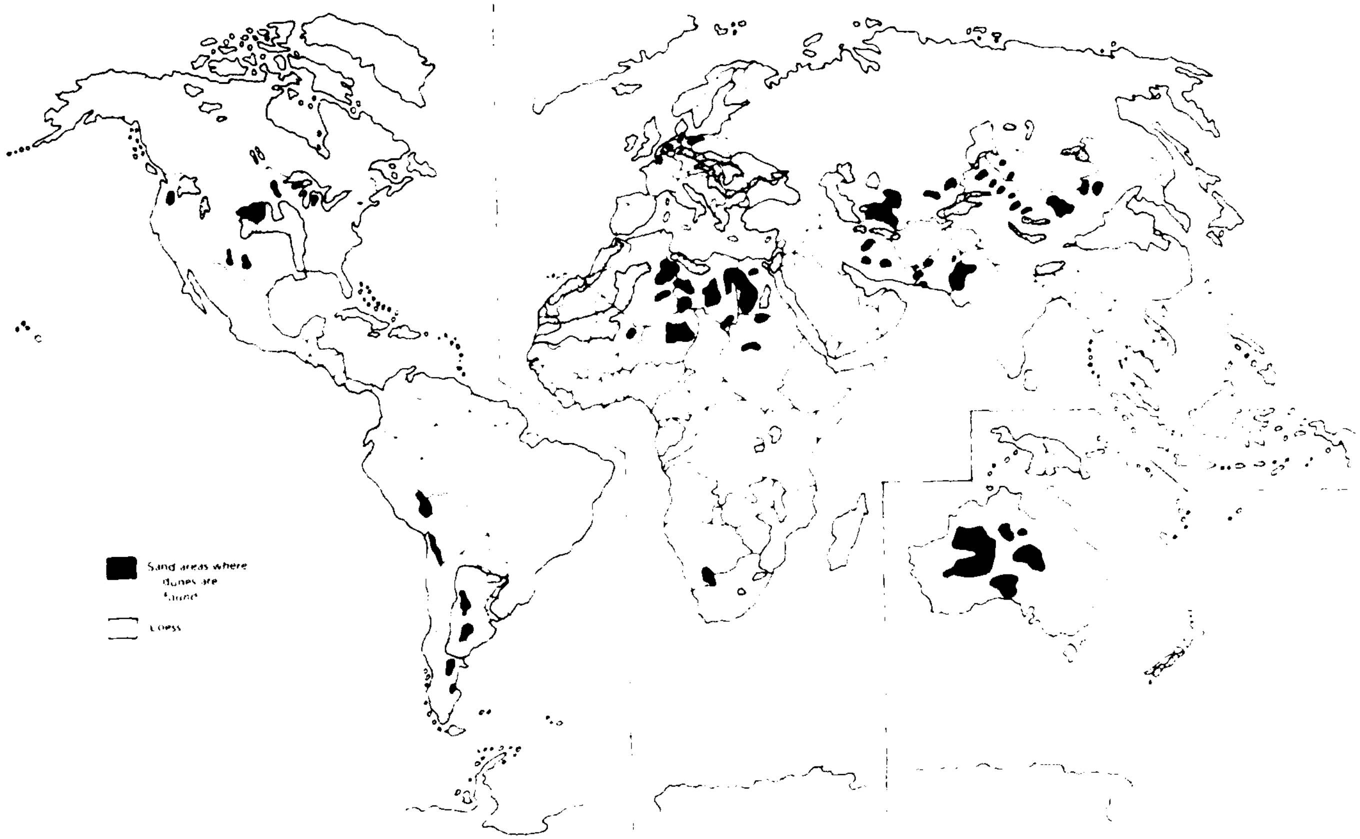
Topographic map, air photo, and surface roughness data elements are described for Eolian forms in the following paragraphs. At the end of this section, the results of topographic map and air photo surface roughness measurements are tabulated.

*From Way, D.S., Terrain Analysis, 1978, © Dowden, Hutchinson & Ross, Inc., Stroudsburg, PA.

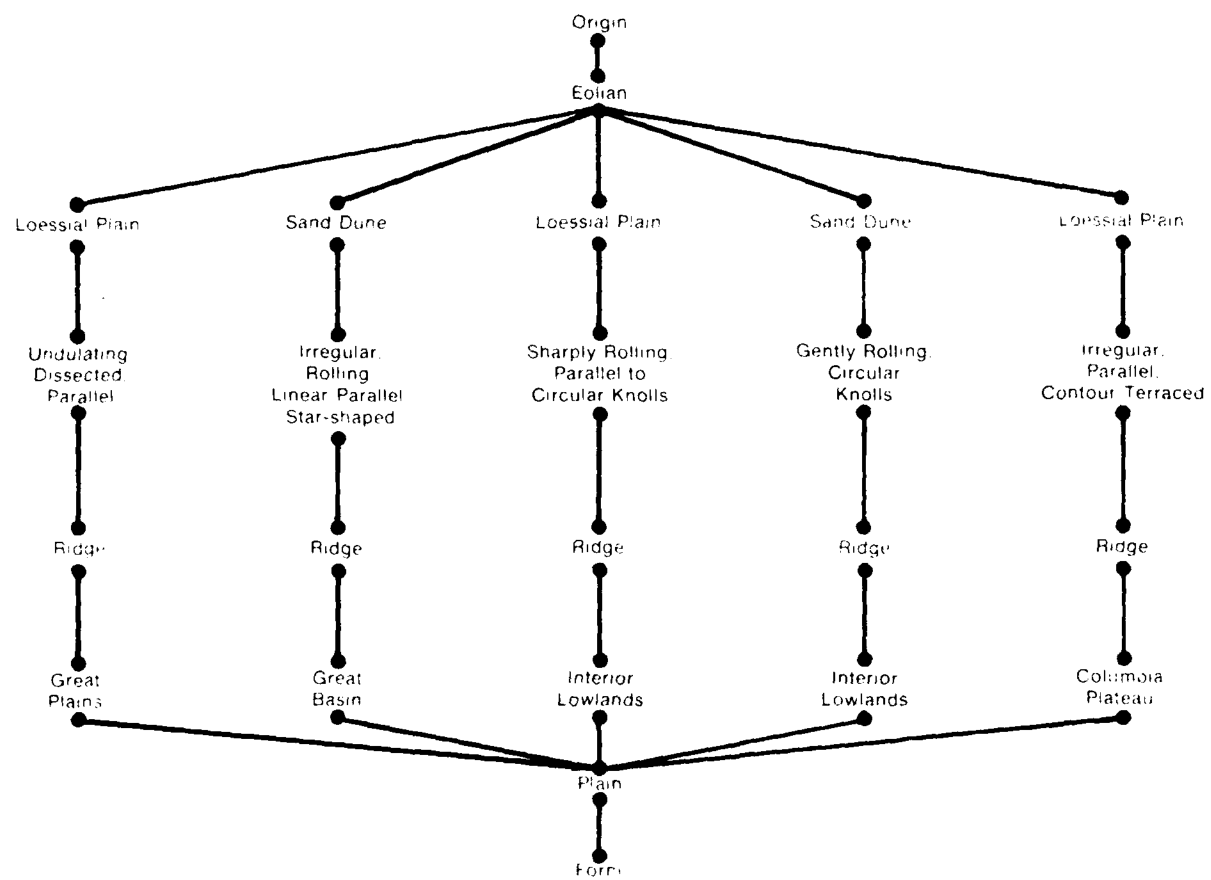


Distribution of Eolian Landforms Within the United States.

Source: Way, D.S., Terrain Analysis, 1978. © Dowden, Hutchinson & Ross, Inc., Stroudsburg, PA, p. 267.



Distribution of Eolian Landforms Around the World.
Source: Way, D.S., Terrain Analysis, 1978, © Dowden, Hutchinson & Ross, Inc., Stroudsburg, PA, p. 268.



This Flow Diagram is Used to Determine the Relationship of Origin to Form for Each of the Eolian Landforms Illustrated in Section 7

7.3.1 Loessial Plain/Loessial Plain

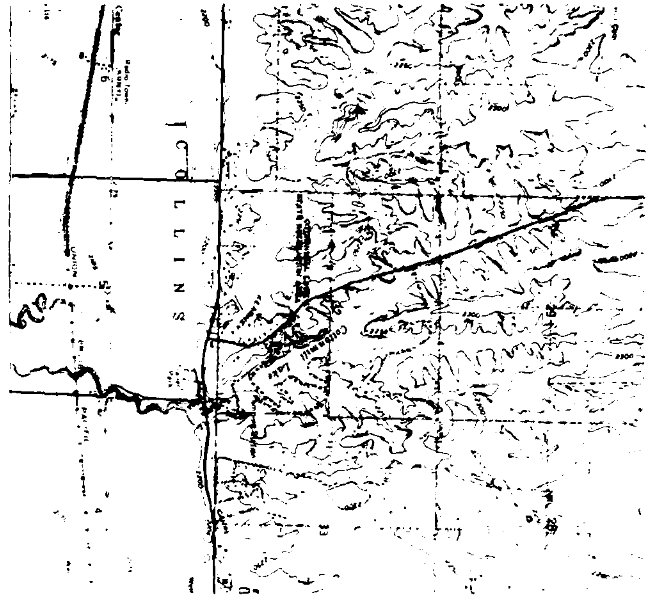
Topographic Map of Loessial Plain, Patoka, IN

TOPOGRAPHIC MAP DATA ELEMENTS
LOESSIAL PLAIN

1. County State/Country
   Gibson County, Indiana
2. USGS Quad or US Army Topo Series
   Patoka, Indiana (1959)
   7.5 minute series 1:24,000
   (reduced to 1:50,000)
3. Land Use
   Agriculture, wooded, natural cover
4. Special Features
   Dips and knolls, severe erosion
5. Form
   Ridge
6. Texture
   Medium

TOPOGRAPHIC MAP DATA ELEMENTS
LOESSIAL PLAIN

1. County State Country
   Buffalo County, Nebraska
2. USGS Quad or US Army Topo Series
   Alfalfa Center, Nebraska (1974)
   7.5 minute series 1:24,000
   (reduced to 1:50,000)
3. Land Use
   Agriculture, natural cover
4. Special Features
   Many small hills with little elevation difference
5. Form
   Ridge
6. Texture
   Medium



Topographic Map of Loessial Plain, Atlanta Center, NE

SURFACE ROUGHNESS DATA ELEMENTS LOESSIAL PLAIN

Irregularities	SR [illegible] Many large irregularities
Form	Rolling, undulating, smooth, rounded, somewhat parallel-oriented hills [illegible] catsteps and pinnacles are prevalent in dissected areas; steep cliffs are adjacent to the primary waterways
Gully Characteristics	Gullies are vertically sided and [illegible] shaped
Color (Photo Gray Tones)	Photo gray tones are light to dark gray, primarily associated with the various stages of the [illegible] cultivation
Land Use	Agriculture [illegible] the entire plain is in cultivation [illegible]
Vegetation	[illegible]
Soil Rock	[illegible]
Relief	[illegible] waterways
Slope	[illegible]

SURFACE ROUGHNESS DATA ELEMENTS LOESSIAL PLAIN

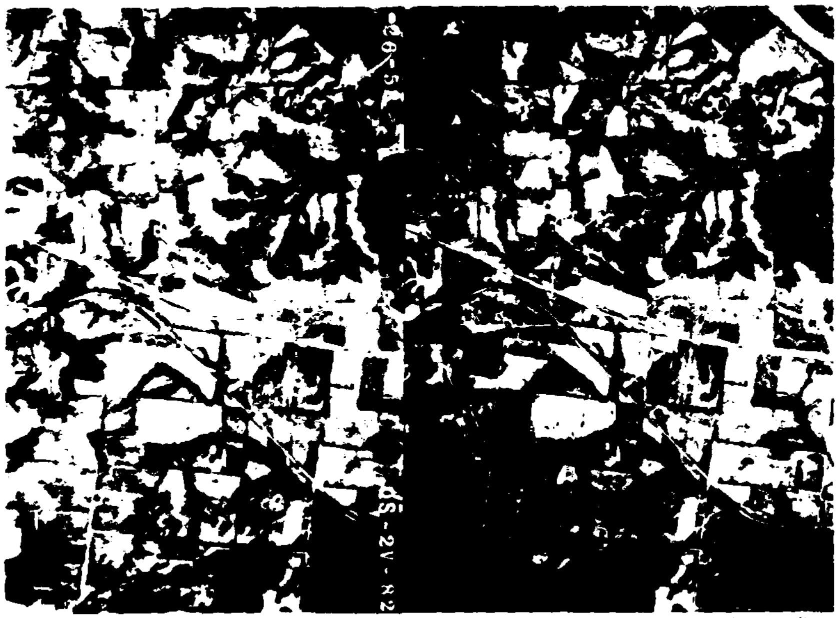
Irregularities	SR 3 Many small irregularities
Form	Pinnacle remnants are seen in the lowlands; a flood plain with indefinite transitional zone bounds the loess deposits
Drainage	The drainage pattern is a combination of pinnate and dendritic
Gully Characteristics	Broad saucer to U-shaped gullies
Color (Photo Gray Tones)	Light to soft gray tone; the light tones are associated with varying stages of cultivation
Land Use	Cultivation is present at all elevations
Vegetation	Scattered tree lots and fencerows are common
Soil Rock	A flood plain with indefinite transitional zone bounds the loess deposits
Relief	Highly dissected, low relief
Slope	Steep where dissected

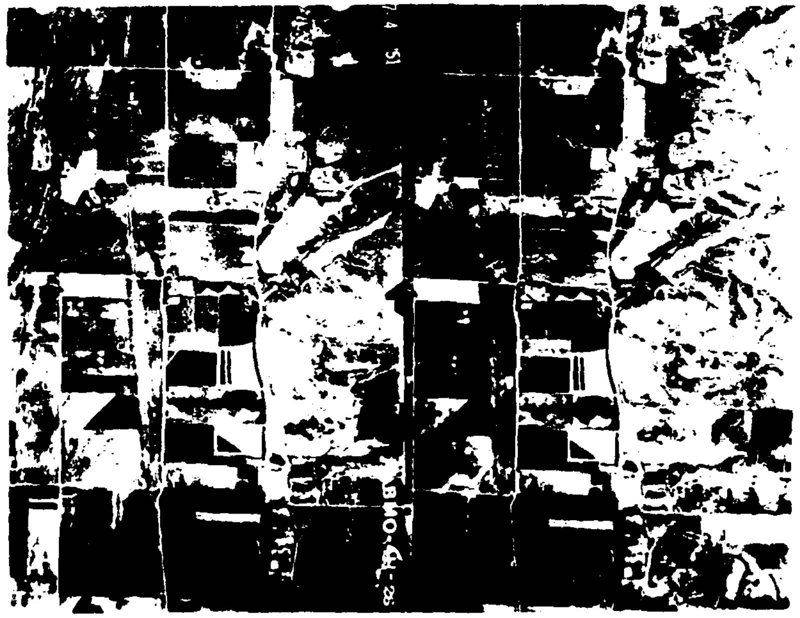
PHOTO PATTERN DATA ELEMENTS: LOESSIAL PLAIN
Photos [illegible] 1958
Physiography
[illegible] Lowlands — This low, gently rolling prairie land, an area created by [illegible] glaciation, is characterized by level plains surrounded by hills, ridges and [illegible], the fringe forms of which are often covered with [illegible] terrace or ridge-like uplands formed by wind-blown [illegible]

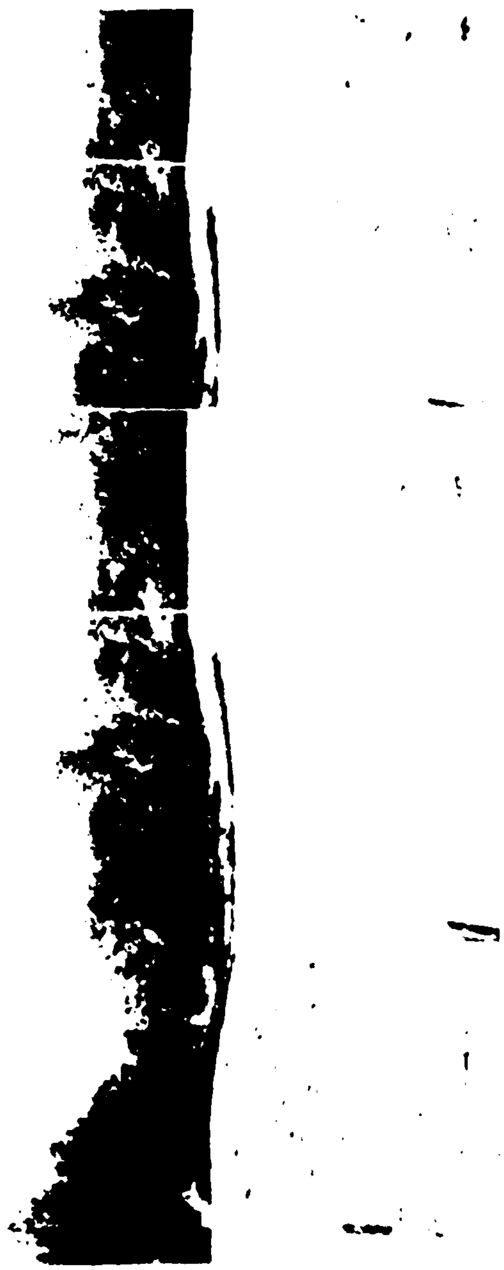
ELEMENTS	DESCRIPTORS
Form	Ridges sharply irregular rolling upland plain with parallel ridges, knolls
Drainage	Frond-like parallelism, complex dendritic, fern-like pattern
Gully Characteristics	Steep, short, U-shaped gullies, parallel frond-like drainage ways
Special Features	Dissected topography, U-shaped gullies, parallel frond-like drainage ways
Color (Photo Gray Tones)	Light gray where crops or open terrain are found, dark where forest-covered
Land Use	Forestry and farming
Vegetation	Dense tree growth in valleys, cultivated elsewhere unless slopes are too steep

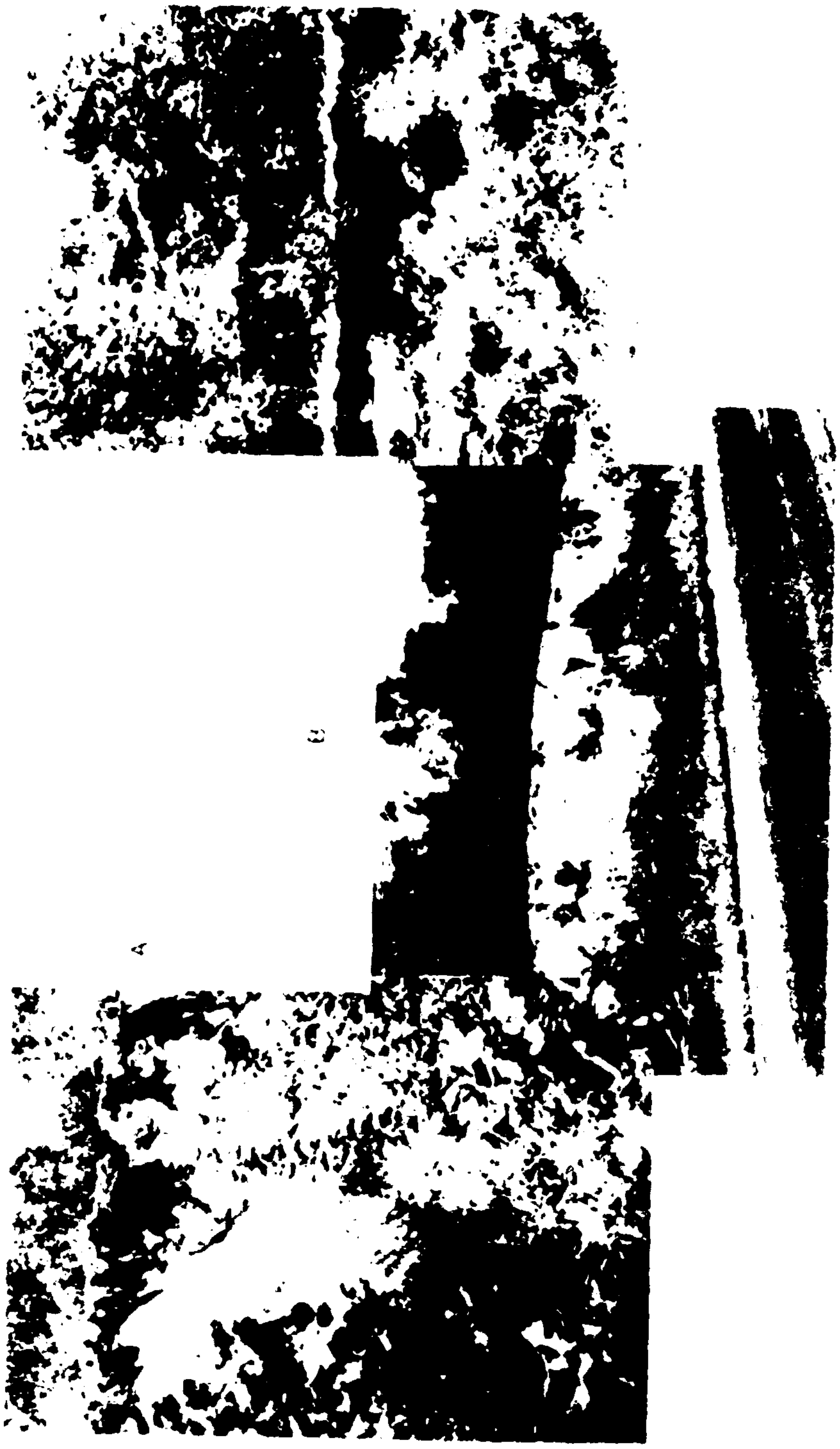
PHOTO PATTERN DATA ELEMENTS: LOESSIAL PLAIN
Photos BMO 4H 25, 26, 1951
Physiography
The Great Plains — [illegible] region [illegible] numerous grass-covered dunes interspread with lakes and ponds as well as dissected, plateau-like areas. These are primarily grazing areas, but irrigation projects are improving agricultural prospects [illegible]

ELEMENTS	DESCRIPTORS
Form	[illegible]
Drainage	Well developed, nearly parallel pattern, modified dendritic at headwater areas, often pinnate pattern occurs within valley ridge system
Gully Characteristics	Broad, flattened, box-shaped [illegible] steep sides and flat steps [illegible]
Special Features	[illegible] box-shaped [illegible] pattern
Color (Photo Gray Tones)	[illegible]
Land Use	Agriculture [illegible]
Vegetation	Grassland









Loessial Plain -- Gully Features Northwest of Cotton Mill Lake Recreation Area, Nebraska. BMO-4H-25

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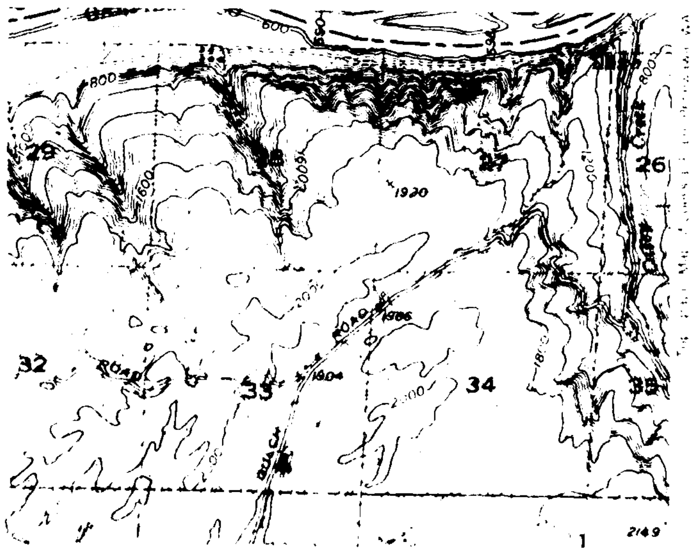
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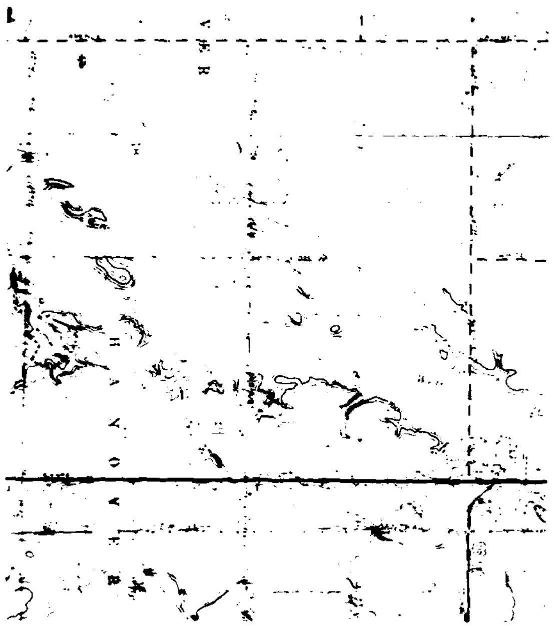
7.3.3 Dune, Sand/Dune, Sand



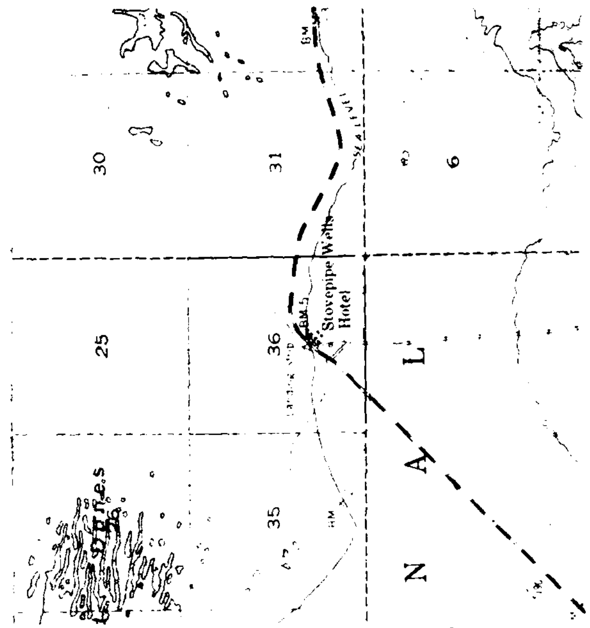
Topographic Map of Sand Dunes St John IN

TOPOGRAPHIC MAP DATA ELEMENTS
DUNE SAND

1. County State Country
   Lake County Indiana
2. USGS Quad or US Army Topo Series
   St John Indiana (1962)
   7.5 minute series 1:24 000
   (reduced to 1:50 000)
3. Land Use
   Agriculture woods ponds
4. Special Features
   Multiple circular knolls
5. Form
   Ridge
6. Texture
   Medium

SURFACE ROUGHNESS DATA ELEMENTS DUNE SAND

Irregularities	SRI 3 Many small irregularities
Form	Round to oval scattered hills ridges
Drainage	Drainage primarily internal
Gully Characteristics	Few V shaped gullies drainage primarily internal
Color (Photo Gray Tones)	Photo gray tones alternate from light to dark
Land Use	Few [illegible] are present
Vegetation	Old dunes overgrown with vegetation [illegible] woodlots and grassy vegetation
Soil Rock	[illegible]
Relief	Low
Slope	Moderately steep [illegible]



Topographic Map of Sand Dunes, Stovepipe Wells, CA

TOPOGRAPHIC MAP DATA ELEMENTS
DUNE SAND

1. County State Country
   Inyo County California (1952)
2. USGS Quad or US Army Topo Series
   Stovepipe Wells California
   15 minute series 1:62 500
3. Land Use
   Barren
4. Special Features
   Parallel linear strips
5. Form
   Ridge
6. Texture
   Medium

SURFACE ROUGHNESS DATA ELEMENTS DUNE SAND

Irregularities	SRI 5 Many large irregularities
Form	Series of transverse dunes a few star shapes [illegible] long wave like ridges arranged in parallel the dunes are limited on the south [illegible] alluvial fans
Drainage	No drainage system
Gully Characteristics	No gullies
Color (Photo Gray Tones)	Bright white to light photo gray tone
Vegetation	No vegetation
Soil Rock	Sand
Relief	Low
Slope	[illegible]

PHOTO PATTERN DATA ELEMENTS DUNE SAND
Photos BFJ-1N-72 73 (1954)
Physiography

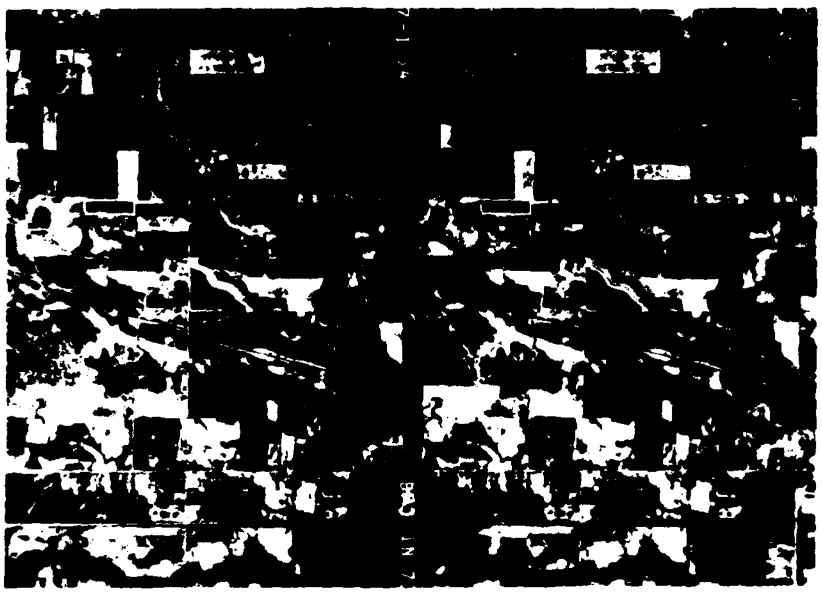
The Interior Lowlands — This area is characterized by low gently rolling prairie topography created by continental glaciation. Numerous hills usually occurring as belts of small hills adjacent to old lakebeds, are also characteristic of this area.

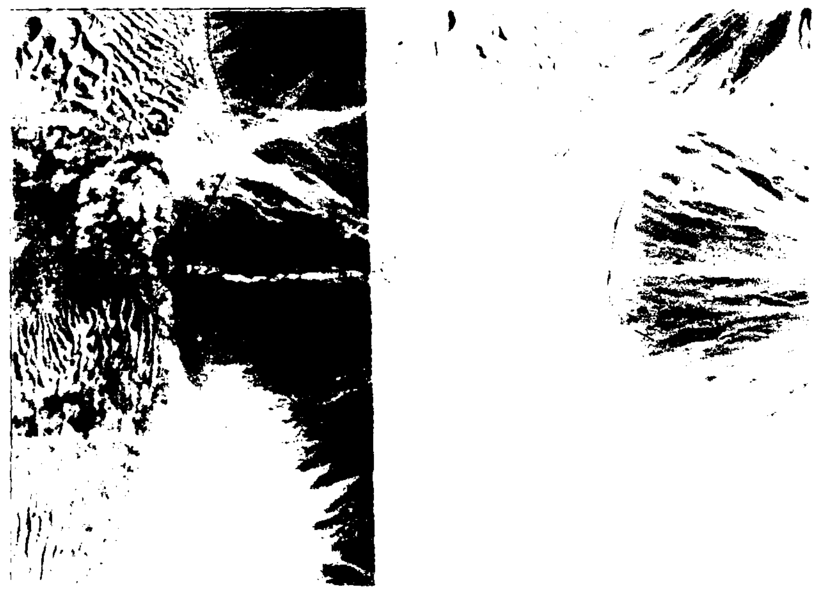
ELEMENTS	DESCRIPTORS
Form	Ridge gently rolling parallel to round knobs
Drainage	Texture — drainage texture coarse (no drainage transverse to beach ridge). No pattern developed (drainage internal)
Gully Characteristics	No gully formation
Special Features	Linear character developed by earlier beach ridges blowouts
Color (Photo Gray Tones)	Dark gray due to vegetation medium gray on grass-covered ridges light gray where sand is exposed through the vegetation
Land Use	Mostly in timber some pasture
Vegetation	Grass and timber

PHOTO PATTERN DATA ELEMENTS DUNE SAND
Photos Stereogram 125. Univ of Illinois (1 65,000) (1948)
Physiography

The Great Basin — The terrain of interest is adjacent to the eastern slopes of the Sierra Nevada within the sandy waste of the Mohave Desert. This area has little rainfall and is below sea level in part. The gently sloping floor of the Basin is covered with fine alluvium which is in turn covered with sand stretches and ridges (Arid)

ELEMENTS	DESCRIPTORS
Form	Ridges, star-shaped irregular shaped hills (dunes), parallel (cross wind) ridges on flat to moderately sloped terrain
Drainage	All internal, no pattern developed
Gully Characteristics	None developed (irregular-shaped slopes) V-shapes can occur
Special Features	Star- and irregular-shaped steep-sloped hills, dunes
Color (Photo Gray Tones)	Bright to very light, grassland is dull gray
Land Use	Rangeland or abandoned
Vegetation	Grassland, salt bush, mesquite, often barren


Stereopair of Sand Dunes


Stereopair of Sand Dunes

Results of Topographic Map Surface Roughness Measurements: Eolian

Data / Form	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	N/A	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	N/A	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	N/A	
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]

Results of Air Photo Surface Roughness Measurements Eolian

Data / Form	[illegible]	[illegible]	Eolian [illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]		[illegible]		[illegible]	[illegible]
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7.3.4 Summary of Surface Roughness Measurements. Eolian Forms

Form	Measurement Method			Average	SRI*
	Empirical	Air Photo	Topographic Map		
Eolian Plain (Semi-arid)	6	4.9	3.9	4.9	5
Eolian Plain (Humid)	5	7.3	4.4	5.6	6
Eolian Plain (Humid)	3	3.0	2.7	2.9	3
Sand Dunes (Arid)	5	7.4	3 (Empirical)	5.1	5
Sand Dunes (Humid)	3	3.1	2.3	2.8	3

*Note. See Section 6 for explanation of method for deriving SRI values

7.4 Introduction to Sedimentary Rock Forms*

Sedimentary rocks are formed by the deposition of sediments transported by streams, ocean or wave currents, ice, or wind. Most sediments are remnants of previously decomposed and disintegrated igneous, sedimentary, and metamorphic rocks, but some are derived from chemical reactions and organic sources. When a particular transporting agent can no longer carry their mass, the sediments are deposited. Variations in the velocity of the transporting agent produce layers or beds whose particles vary in texture and it is the presence of bedding planes that distinguishes sedimentary from igneous rocks, the latter tend to be massive and nonbedded. The bedding planes in sedimentary rock are originally laid down parallel to the earth's surface, but later may be tilted by movements of the earth's crest.

Sedimentary rocks accounting for approximately 75 percent of the earth's exposed land surface occur in two categories. The first category includes clastic or fragmental rocks, such as shales, sandstones, and conglomerates originating from other rocks. The second category are formed from chemical and biochemical (organic) sediments precipitated from solution (examples are calcium carbonate, and limy parts of organisms such as corals, algae, foraminifers, clams, and snails). These sediments include limestone, gypsums, and salt. Large organic or swamp deposits upon lithification become coal and are commonly found interbedded with other sedimentary materials. Coal is not included here.

Most sedimentary deposits originate underwater in oceans resultings from stream and river system flow. The sediments consist of gravels, sands, silts, and clays; the resulting deposits vary in texture according to the distance from shore and water velocities at the time of deposition.

Distribution – Some regions of the World containing well-consolidated sedimentary rocks are listed in the following paragraphs.

North America, United States and Canada — The regions include only those where residual soils have developed from weathered sedimentary rocks. In the United States, sedimentary rocks of all types and attitudes are found in areas adjacent to the Appalachian Mountains, the central plains, and scatterings throughout the Rocky Mountains.

A band of interbedded sedimentary rock extends across most of Saskatchewan and eastern Alberta across the Northwest Territories just west of Great Bear Lake and into the Alaskan north slope.

South and Central America – Sedimentary rocks are found in southern Argentina and throughout parts of Brazil.

Africa – Sedimentary rocks are widespread across Africa with surfaces of residual soils.

Europe – Sedimentary rocks are found associated with most European mountain ranges. Southern England, Ireland, and France have the major formations.

Asia – Large portions of western Russia and central Siberia consist of sedimentary rock with scattered systems occurring through Tibet. Less exposures can be found in Cambodia and Thailand.

Australia – Sedimentary rocks are found in most of Queensland, parts of South Australia, and parts of Western Australia.

Pacific and Caribbean Regions – Well-consolidated sedimentary rocks occur in the islands of coral formations and coquina.

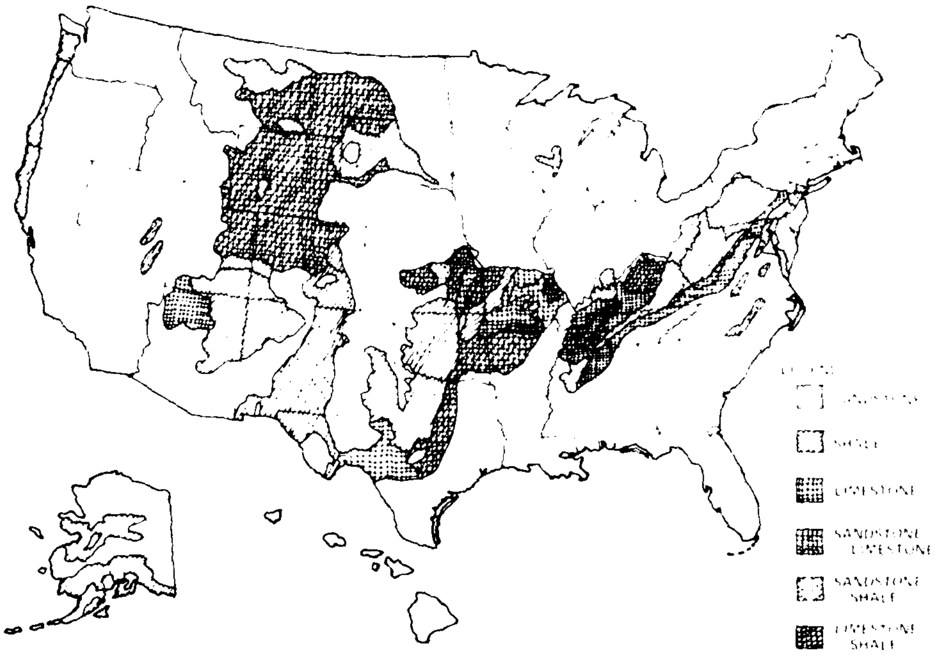
Sedimentary deposits are found in parts of Cuba, Haiti, the Dominican Republic, and Puerto Rico; limestone formations are most common.

The maps on pages 7-70 and 7-71 show the United States and World distribution of Sedimentary Rock forms.

A flow diagram for Sedimentary Rock forms (7-72) illustrates how the terrain analyst may enter this section to develop information on a landform of sedimentary origin. The diagram may be entered at the top to find a given landform based on origin or entered at the bottom of the diagram when based on form.

Topographic map, air photo, and surface roughness data elements are described for Sedimentary Rock forms in the following paragraphs. At the end of this section, the results of topographic map and air photo surface roughness measurements are tabulated.

*From Way, D.S., Terrain Analysis, 1978, © Dowden, Hutchinson & Ross, Inc., Stroudsburg, PA.

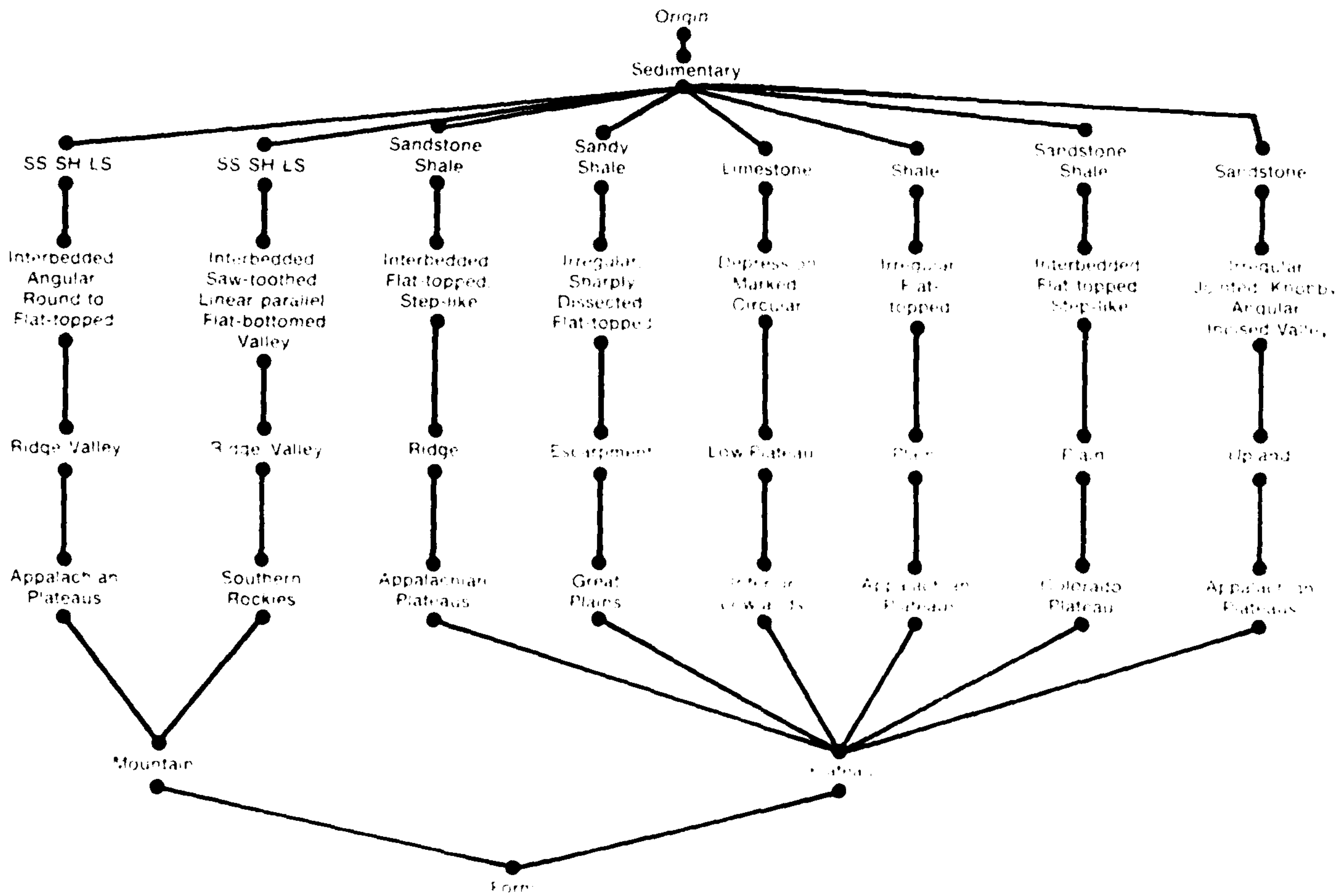


Distribution of Well-Consolidated Sedimentary Rock Parent Materials in the United States. Note — Glaciated Areas Are Not Shown.

Source: Way, D.S., Terrain Analysis, 1978, © Dowden, Hutchinson & Ross, Inc Stroudsburg, PA, p. 83.

World Distribution of Well-consolidated Sedimentary Rocks. Not all the Areas Shown Contain Ideal Sedimentary Residual Soils Since Glacial, Eolian, or Fluvial Processes May Have Further Modified Them.

Source: Way, D.S., Terrain Analysis, 1978, © Dowden, Hutchinson & Ross, Inc., Stroudsburg, PA, p. 84



This Flow Diagram is Used to Determine the Relationship of Origin to Form for each of the Sedimentary Landforms Illustrated in Section 7

7.4.1 Sandstone/Limestone

Topographic Map of Flat Lying Sandstone Upland Lancing TN

TOPOGRAPHIC MAP DATA ELEMENTS
SANDSTONE

1. County, State Country
   Morgan County, Tennessee
2. USGS Quad or US Army Topo Series
   Lancing, Tennessee 1952
   7.5 minute series 1:24,000
   reduced to 1:50,000
3. Land Use
   Park, forested, [illegible]
4. Special Features
   Huge hills, deeply incised [illegible] forest cover
5. [illegible]
   [illegible]
6. Texture
   Dense

TOPOGRAPHIC MAP DATA ELEMENTS
LIMESTONE

1. County, State Country
   Hart, Barren [illegible] County, Kentucky
2. USGS Quad or US Army Topo Series
   Horse Cave, Kentucky 1966
   7.5 minute series 1:24,000
   reduced to 1:50,000
3. Land Use
   Agriculture, woodlots, [illegible]
4. Special Features
   Karst topography
5. Form
   [illegible] area
6. Texture
   Medium

Topographic Map of Flat Lying Limestone Upland Horse Cave KY

SURFACE [illegible] DATA ELEMENTS SANDSTONE

[illegible]	SRP [illegible] Many, [illegible]
Form	[illegible] mass [illegible] and forested [illegible]
Drainage	The drainage [illegible] with [illegible] shaped [illegible]
[illegible] Characteristics	[illegible]
Tone / Photo [illegible] Tones	[illegible] in forest covered areas.
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

SURFACE [illegible] DATA ELEMENTS LIMESTONE

[illegible]	[illegible] 4 Many, [illegible] some [illegible]
Form	[illegible] sinkholes [illegible] slightly [illegible] plain bounded by an upland mass
Drainage	[illegible] sinkholes in plain some [illegible] water [illegible] parallel drainage [illegible] drainage on plain
Color / Photo Gray Tones	Generally [illegible] tone but dark in sinkholes and depressions
Land Use	Agriculture [illegible] cultivated except where water [illegible] excessively wet
Vegetation	Forested [illegible] scattered trees on plain
Soil Rock	Rock outcrops [illegible] numerous boulders in upland, fence rows [illegible] plain
Relief	Bold relief [illegible]
Slope	Steep [illegible] ridges

PHOTO PATTERNS AT A [illegible] [illegible] [illegible]

[illegible]

[illegible]

[illegible]

ELEMENT	DESCRIPTION
[illegible]	[illegible] coarse [illegible] steep, sharp [illegible] [illegible] [illegible] plateau.
[illegible]	[illegible] modified [illegible] [illegible] pattern [illegible]
[illegible]	[illegible] shaped to [illegible] shaped or U shaped
[illegible]	Steep [illegible] sharp, forested ridges [illegible]
[illegible] Photo Gray Tones	[illegible] medium grays, light grays found in [illegible] sandstones, darker grays to black are result of greater density of vegetation
Land Use	Rangeland and limited farm and forested
Vegetation	Forests, brush

PHOTO PATTERNS AT A [illegible] [illegible]

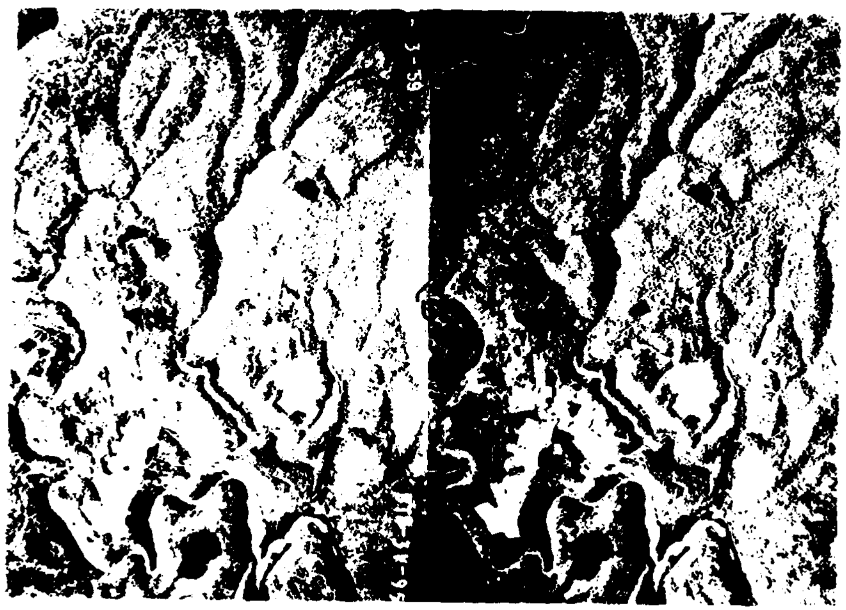
Photo: A[illegible] [illegible]

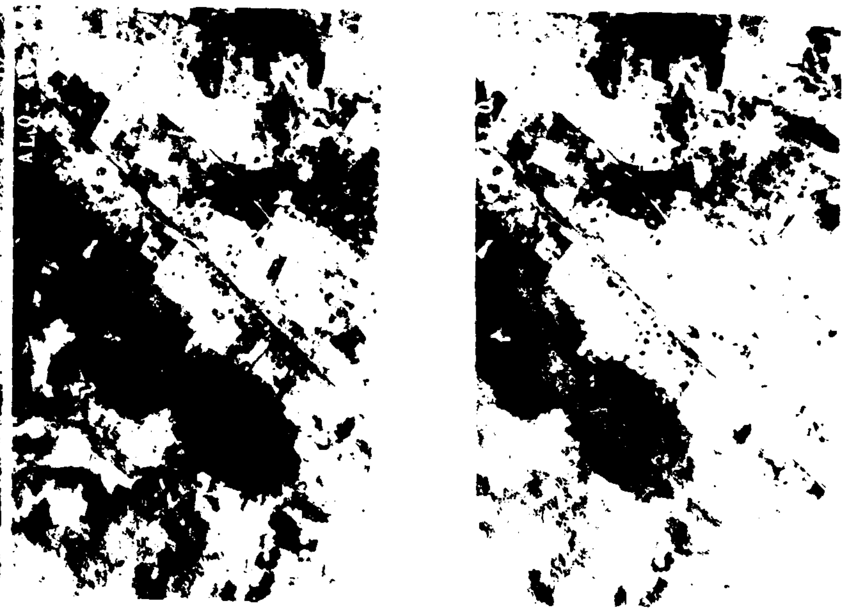
Physiography

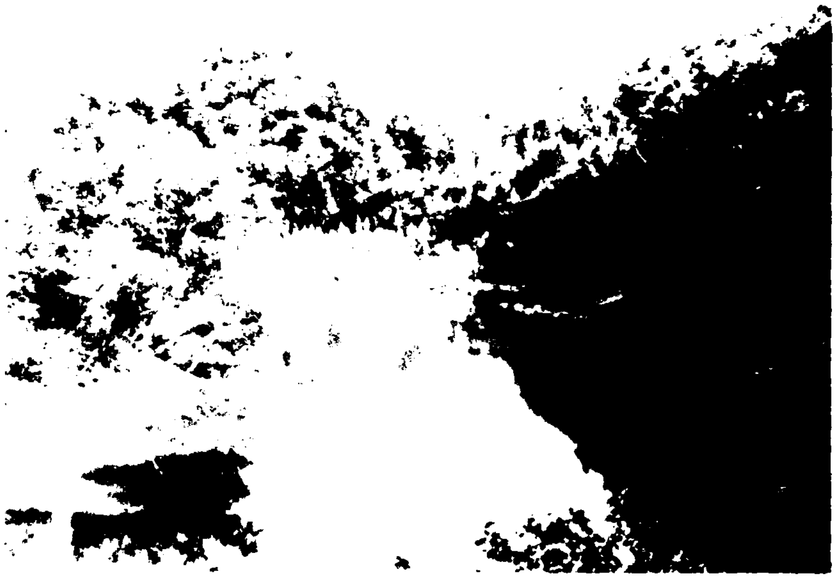
The Interior Lowland [illegible] almost horizontal [illegible] Grass Basin. [illegible] limestone formation [illegible]

Field: Humid

ELEMENT	DESCRIPTION
Form	[illegible]
Drainage	Internal [illegible]
Gully Characteristics	Few [illegible]
Special Features	Sinkholes
Color Photo Gray Tones	Gray to dark gray depressions [illegible] dark when covered with vegetation, light when [illegible] water
Land Use	Generally cultivated agriculture
Vegetation	Tree cover on ridge

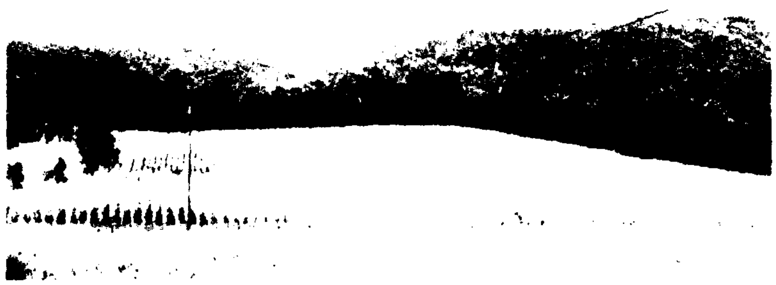






Sandstone Upland — Knobs and U-Shaped Ridges. BTB 3V95

Sandstone Upland Ridge — Vegetation Density. BTB 3V95



Sandstone Upland (Humid) — Flat-Lying Agricultural Plot. BTB 3V95

Sandstone Upland Ridge -- Valley Feature BTB 3V95

Limestone — Outcrop Near Horse Cave, Ky. ALO 48-36

Limestone — Cultivated Sinkhole

7.4.2 Shale/Sandy Shale

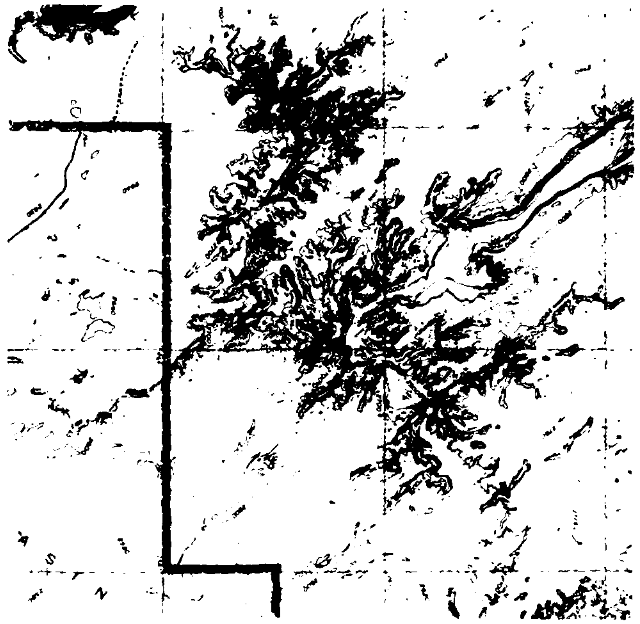
Topographic Map [illegible] Shale [illegible] Chillicothe East Kingston, Ohio

TOPOGRAPHIC MAP DATA ELEMENTS SHALE

1. County State Country
   Ross County Ohio
2. USGS Quad or US Army Topo Series
   Chillicothe East Kingston, Ohio (1975)
   7.5 minute series 1:24 000 (reduced to 1:50 000)
3. Land Use
   Forested agriculture
4. Special Features
   Smooth-sloping hills
5. Form
   Plain
6. Texture
   Medium

TOPOGRAPHIC MAP DATA ELEMENTS SANDY SHALE

1. County State Country
   Pennington County South Dakota
2. USGS Quad or US Army Topo Series
   Quinn Table SE South Dakota (1960)
   7.5 minute series 1:24 000 (reduced to 1:50 000)
3. Land Use
   Barren
4. Special Features
   Fine drainage severe erosion
5. Form
   Escarpment
6. Texture
   Dense



Topographic Map [illegible] Sandy Shale [illegible] Quinn Table SE, S.D.

[illegible] DATA ELEMENTS SHALE

[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
	[illegible]

SURFACE ROUGHNESS DATA ELEMENTS SANDY SHALE

Irregularities	SRL 8 Many [illegible] spaced [illegible] irregularities
Form	Rugged [illegible] topography [illegible] dissected steep slopes some broad flat [illegible] areas
Drainage	Very fine textured [illegible] pattern
[illegible]	[illegible]
Color [illegible]	[illegible]
Vegetation	[illegible]
Soil Rock	[illegible]
Relief	[illegible]
Slope	Steep

PHOTO PATTERN DATA ELEMENTS: SHALE

[illegible]

The [illegible] Plateau ... The Allegheny Plateau, Kanawha Section, is [illegible] dissected by westward-flowing streams; flat uplands [illegible] mesa-like remnants; the upper strata [illegible] horizontal outcrops in valley walls within the flat-lying [illegible]

ELEMENTS	DESCRIPTORS
[illegible]	Plain, smooth to rolling, irregular
[illegible]	Dendritic with no angular patterns; very little moisture is absorbed
[illegible]	Sag and swell type; V-notches in steep slopes
[illegible]	Dendritic drainage pattern
[illegible]	Varies from gray to dark gray
[illegible]	Cultivated field crops, or heavily forested
[illegible]	Heavily forested on the steep slopes

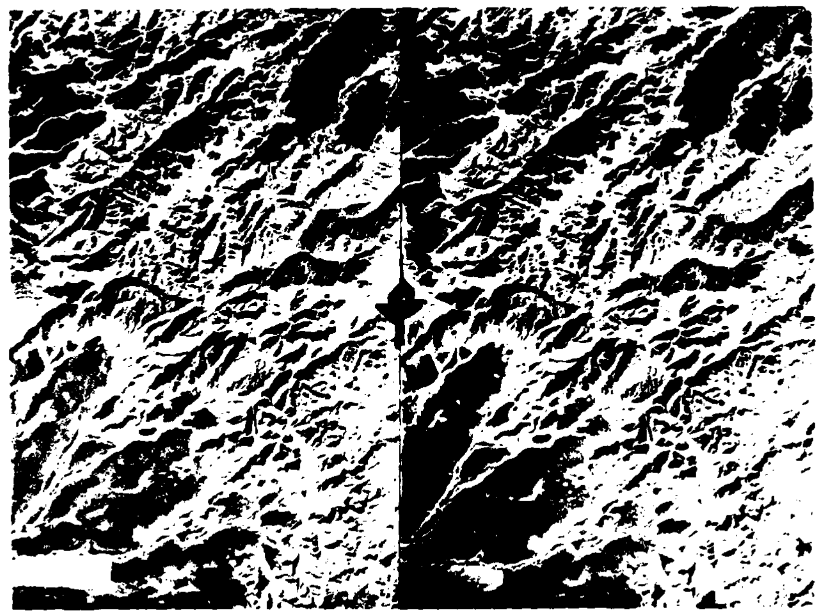
PHOTO PATTERN DATA ELEMENTS: SANDY SHALE

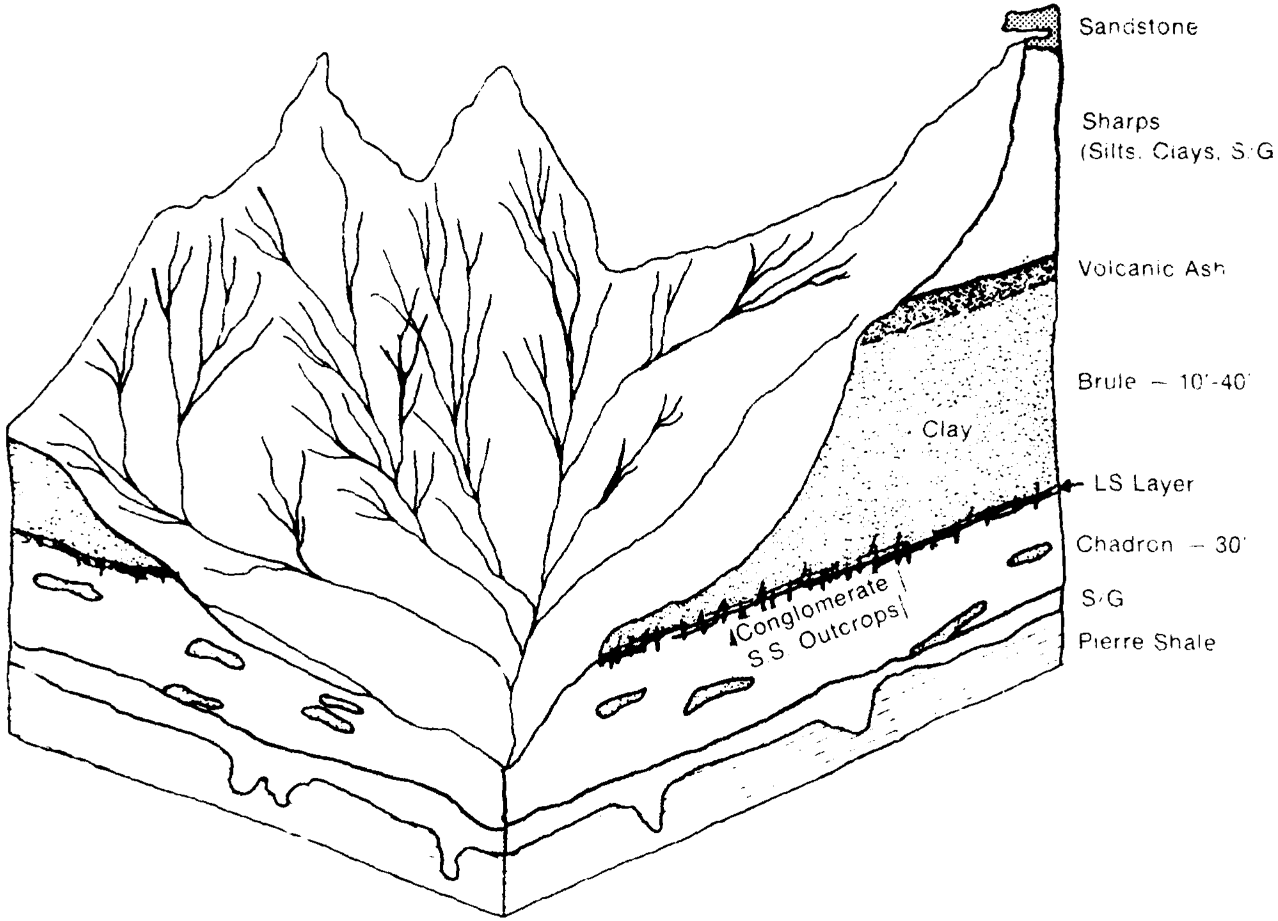
Photos BOI 7N 169 170 (1954)

Physiography

<u>The Great Plains</u>. This is a region of buttes, mesas, and badlands called the Missouri <u>Plateau</u>. This ridge plain, badland feature occurs as an old plateau on the northwestern fringe of the High Plains. It is known as the Break of the Plains, <u>an escarpment</u> characterized by badland forms, steep slopes, and isolated buttes and peaks. These areas were never glaciated. (Semi-arid)

ELEMENTS	DESCRIPTORS
Form	Escarpment, strong relief, narrow, sharp ridges and very V-shaped gullies, dissected, steep hillsides
Drainage	Super fine, sub-parallel
Gully Characteristics	Extremely V-shaped, fine-textured erosion pattern; area is extremely susceptible to erosion due to the aridity which eliminates the possibility for establishment of vegetation; also soil is fine and relatively soft
Special Features	Super sharp ridges and extremely fine drainage pattern
Color (Photo Gray Tones)	Light on ridges, dark on slopes and in valleys
Land Use	Scientific excavation, recreation
Vegetation	Mostly barren with some grass and scrub growth in valleys





[illegible] Diagram of Bad Lands, Sandy Shale Upland, Quinn Table SE S.D

7.4.3 Sandstone-Shale/Sandstone-Shale

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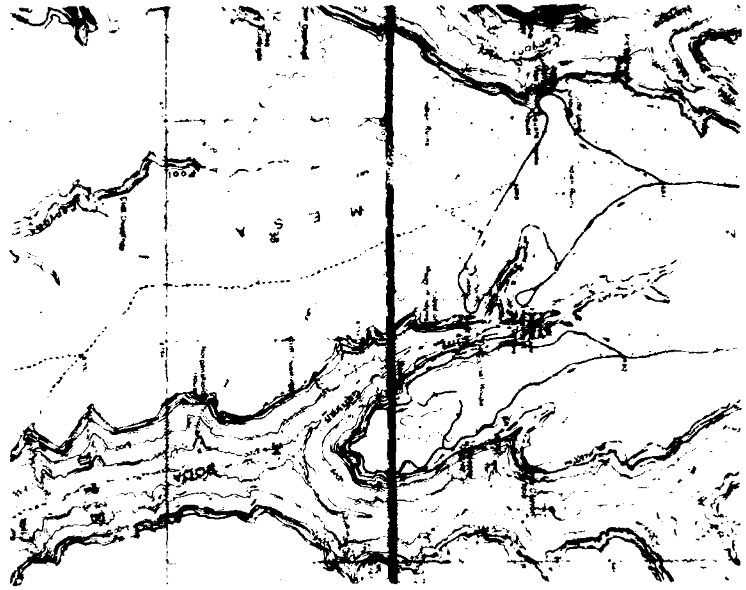


TOPOGRAPHIC MAP DATA ELEMENTS
SANDSTONE SHALE

USGS Quad or US Army Topo Series
Lancaster, Ohio 1974

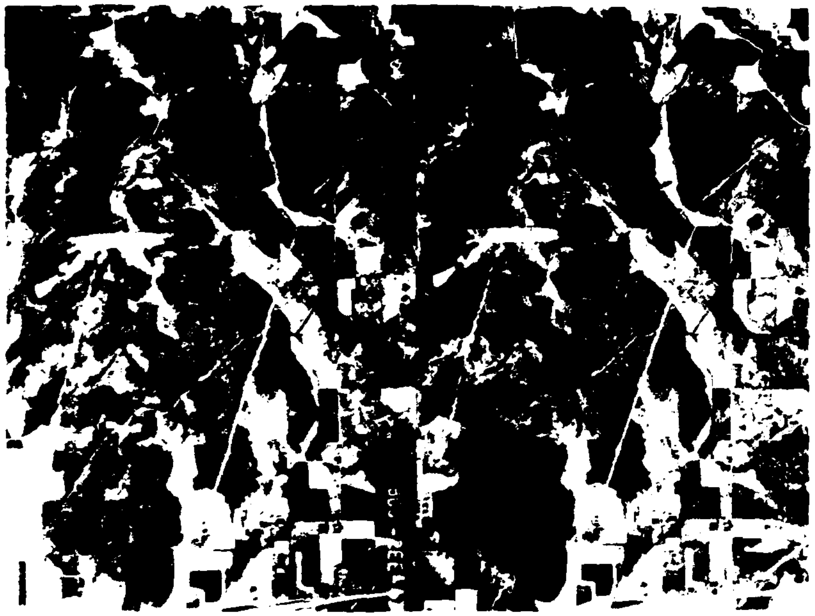
[illegible] PATTERN DATA ELEMENTS SAND[illegible]NE SHALE
[illegible]
[illegible]
[illegible] Allegheny Plateau [illegible] Much of the area is forested [illegible]

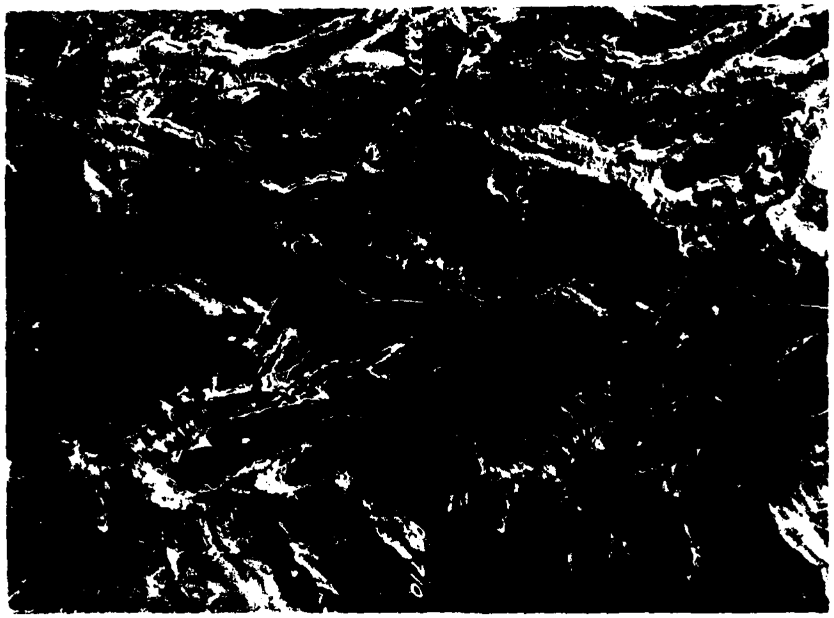
ELEMENTS	DESCRIPTORS
[illegible]	R[illegible] flat topped steeply sloping interbedded layers with sandstone capping shale more grad[illegible]
Drainage	Dendritic medium to coarse
[illegible] Characteristics	[illegible] sag-and swell gullies indicative of cohesive soils
Special Features	Steep slopes heavily forested
Color (Photo Gray Tones)	Sandstone appears lighter due to better drainage (dark where forested) shale appears darker
Land Use	Sandstone mostly forested shale has some agriculture
Vegetation	Mostly forested on sandstone some cultivation on shale

PHOTO PATTERN DATA ELEMENTS SANDSTONE SHALE
Photos DZ 710 711 (1937
Physiography

The Colorado Plateau — The canyon lands are a flat lying youthfully dissected plateau region containing a slightly bent-up layered system tilting westward. Rivers form deep gorges separating high tablelands with occasional conspicuous volcanic cones or peaks. These high-relief tablelands have heavy forest growth; the lower tablelands are deserts. (Semi-arid)

ELEMENTS	DESCRIPTORS
Form	Plain upland interbedded sandstone and shale hills under semi-arid conditions the beds are flat lying irregular box-shaped steep-sloped upland sandstone and shale plateau
Drainage	Sub-parallel open controlled dendritic. The openness of drainage and coarse pattern indicates internal drainage
Gully Characteristics	Sharp V's across sandstone ledges relatively steep gradients throughout area
Special Features	Rugged box-shaped steep slopes
Color (Photo Gray Tones)	Light on sandy areas banding alternates light dark
Land Use	Undeveloped or rangeland forested table tops
Vegetation	Scrub growth mesquite sagebrush in ravines low areas





7.4.4 Sandstone-Shale-Limestone/Sandstone-Shale-Limestone

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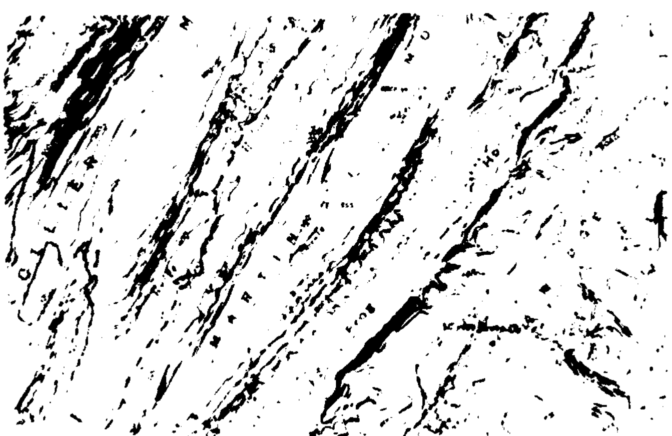

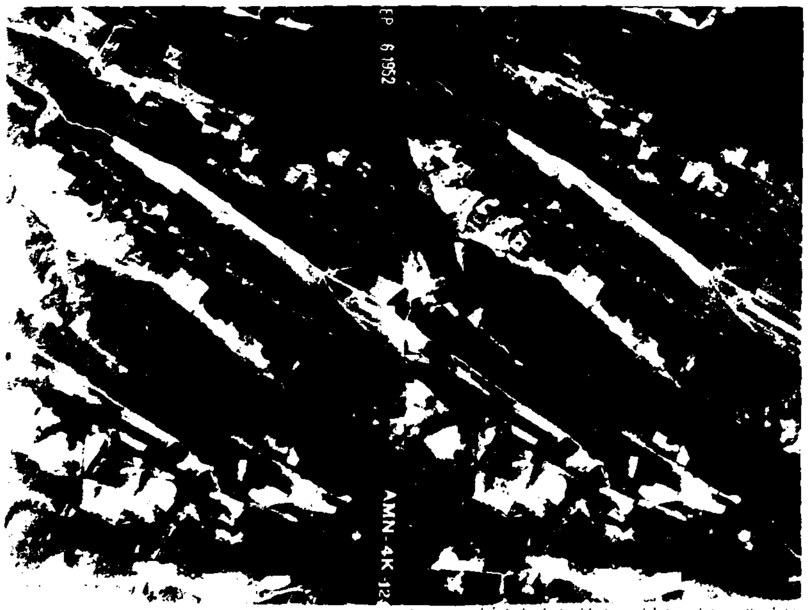
EP 6 1952
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AIL-2B-8

Results of Topographic Map Surface Roughness Measurements: Sedimentary Rock Forms

Form / Data	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Contour Bends [illegible]	14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14	[illegible]
Bend Wave Length [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Bend Amplitude [illegible]	[illegible]	[illegible]	13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fencerow Frequency (No. 5 cm)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Calculated SRI	[illegible]	[illegible]	[illegible]	3.8	4.4	[illegible]	[illegible]	[illegible]

Results of Air Photo Surface Roughness Measurements: Sedimentary Rock Forms

Form / Data	Sandstone	[illegible]	[illegible]	[illegible]	Sandstone [illegible]	[illegible]	Sandstone [illegible]	[illegible]
Gully Frequency (No. 5 [illegible])	[illegible]	[illegible]	19	[illegible]	4.4	[illegible]	[illegible]	[illegible]
Contour Bends (No. 5 cm)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	[illegible]	[illegible]
Fencerow Frequency (No. 5 cm)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Point Obstacles (No. 5 cm)	[illegible]	[illegible]	14.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Linear Obstacles (No. 5 cm)	[illegible]	[illegible]	[illegible]	[illegible]	2.4	[illegible]	[illegible]	[illegible]
Tonal Changes (No. 5 cm)	3.8	[illegible]	4.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Calculated SRI	[illegible]	[illegible]	8.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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7.4.5 Summary of Surface Roughness Measurements: Sedimentary Rock Forms

Form	Measurement Method			Average	SRI*
	Empirical	Air Photo	Topographic Map		
Sandstone (humid)	5	3.2	4.[illegible]	4	4
Shale (humid)	5	3.[illegible]	[illegible].0	4.4	4
Sandy Shale (arid)	8	8	5.8	8	8
Limestone	4	4.2	3.8	4.0	4
Sandstone-Shale (humid)	5	5.9	4.4	[illegible]	5
Sandstone-Shale (arid)	6	5.8	3.7	5.[illegible]	5
Sandstone-Shale Limestone (humid)	5	4.5	3.9	4.5	[illegible]
Sandstone-Shale Limestone (arid)	8	7.7	2.3	6.0	6

*Note: See Section 6 for explanation of method for deriving SRI values

7.5 Introduction to Igneous Forms*

Igneous rocks are formed by the solidification of magma or molten rock material on or within the surface of the earth. Igneous rocks are classified either intrusive, (formed beneath the surface of the earth), or extrusive (formed on the earth's surface).

Intrusive Igneous Rocks (Granitic Materials) -- Intrusive igneous rocks were solidified from molten rock material beneath the surface of the earth as plutons, regardless of size, shape, or composition. The crystalline structure of igneous plutonic rocks is well developed owing to their slow process of solidification. Plutonic rocks underlie all rock types, forming a platform or basement supporting the surface rocks. Exposure takes place if the overriding materials are weathered or eroded away. Plutonic rocks occur on only 15 percent of the earth's surface.

Extrusive Igneous Rocks (Basaltic Materials) -- Extrusive igneous rocks are of two types. One type is formed by volcanic eruptions which pour molten lava onto the earth's surface, where it solidifies. The other type includes fragmental rocks of all sizes which have solidified at the surface of the earth.

Volcanic magma does not develop a large crystalline structure, for the cooling of the material is rapid and the resulting crystalline texture is so fine that it is not apparent without magnification. Most extrusive rocks are dense and glassy in appearance, but they can be filled with gas bubbles or even frothy.

Extrusive rocks occur throughout the world, but account for only about 3 percent of the total exposed continental land surface.

Distribution -- Granite is a predominant igneous intrusive rock form providing the foundation for most of the continental masses and the central core of many mountainous structures. Basaltic and volcanic forms occur scattered across most of the continents in small deposits.

North America, United States and Canada -- The New England states of Massachusetts, Vermont, New Hampshire, and Maine contain massive granitic forms. Other granitic areas include the Adirondack Mountains of northern New York, a large batholith in central Idaho, the Black Hills of South Dakota, the Sierra Nevada region of California, and the northern Cascades in Washington.

Most of the eastern half of Canada has exposed granitic rock. Basaltic formations are found in southcentral British Columbia.

South and Central America -- Igneous granitic intrusions are found in southern Venezuela, southern Guyana, Surinam, French Guiana, northern Brazil, the southeast coast of Brazil and prominent through most of Central America.

Africa -- Igneous granitic formations occupy large areas in Africa including Madagascar. The broadest coverage extends across central Africa, then southward along eastern coastal sections. A large basaltic region extends across central Ethiopia into western Kenya.

Europe -- Norway, Sweden, Finland, and bordering Russian territories consist mainly of granitic materials. Igneous intrusions occupy northern Scotland, central France, and northwestern Spain.

Asia -- Exposed granitic intrusions occur over most of India, Ceylon, the northern portion of the Mongolian Republic, northern Manchuria, and the bordering regions of Siberia.

Australia -- Most of Western Australia is granitic; there are fewer outcrops in the Northern Territory and Southern Australia. No significant basaltic formations are found in Australia.

Pacific and Caribbean Regions -- No significant regional granitic deposits are found in the Pacific island region. Most of the islands of the Pacific central basin are basaltic, including the Hawaiian Islands, the Aleutians, and the foundations of many lagoon-forming islands.

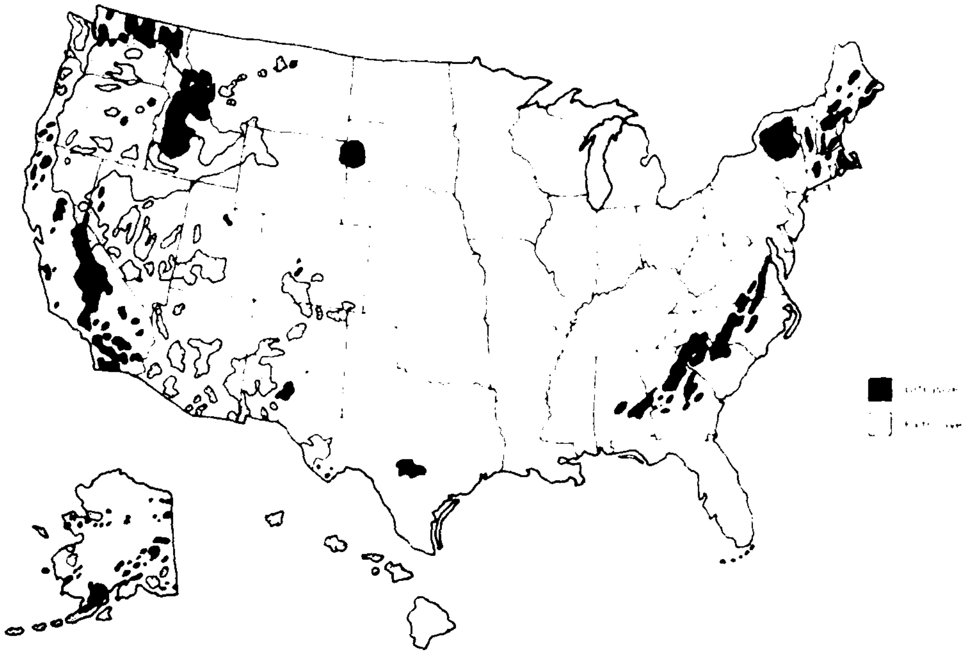
Small, scattered granitic outcrops exist throughout Puerto Rico and the Virgin Islands. The Windward Islands consist of basaltic materials, and scattered deposits are found in the Dominican Republic.

The maps on pages 7-98 and 7-99 show the United States and World distribution of Igneous forms.

A flow diagram for Igneous forms (7-100) illustrates how the terrain analyst may enter this section to develop information on a landform of igneous origin. The diagram may be entered at the top to find a given landform based on origin or entered at the bottom of the diagram when based on form.

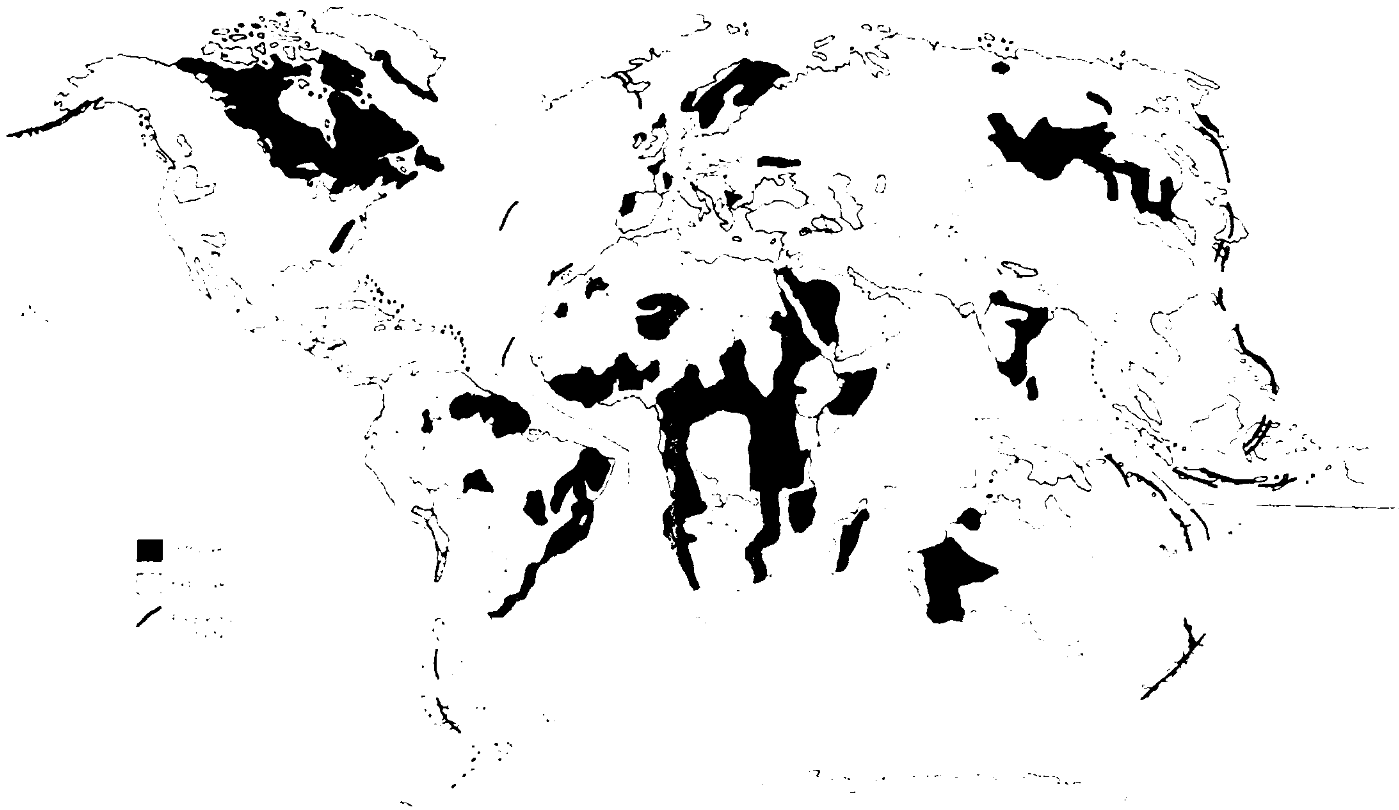
Topographic map, air photo, and surface roughness data elements are described for Igneous forms in the following paragraphs. At the end of this section, the results of topographic map and air photo surface roughness measurements are tabulated.

*From Way, D.S., Terrain Analysis, 1978, ©Dowden, Hutchinson & Ross, Inc., Stroudsburg, PA



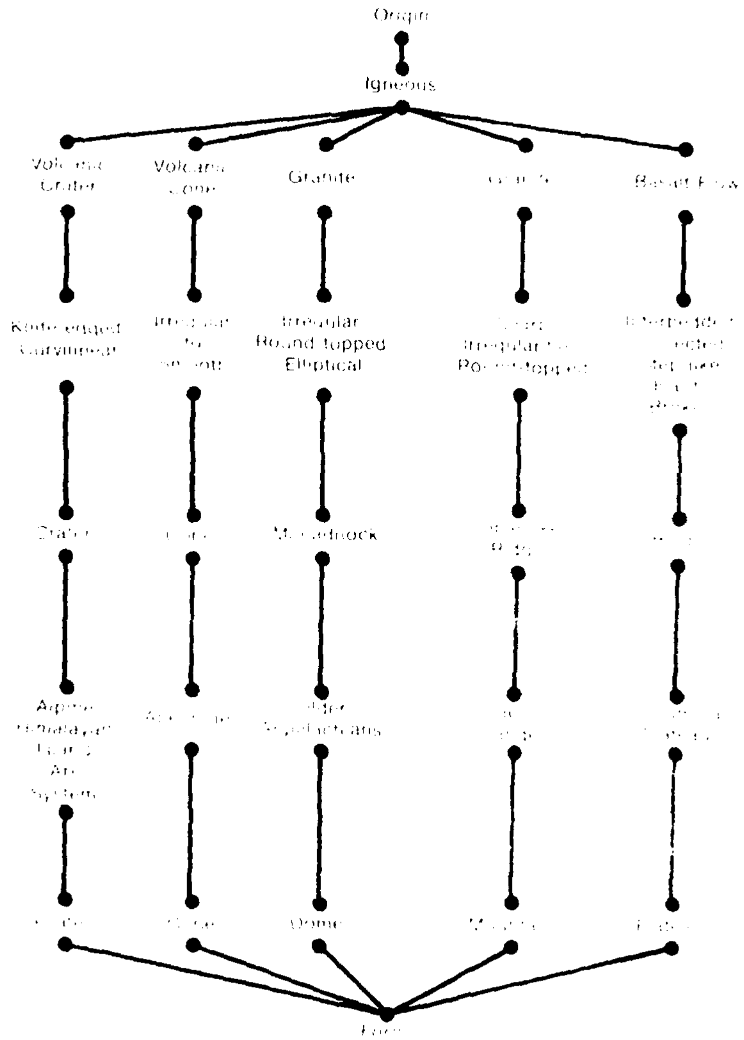
Distribution of Igneous Landforms in the United States.

Source: Way, D.S., Terrain Analysis, 1978. © Dowden, Hutchinson & Ross, Inc. Stroudsburg, PA, p. 143.



Distribution of Major Igneous Formations Throughout the World

Source: Way, D. S., Terrain Analysis, 1978. Dowden, Hutchinson & Ross, Inc., Stroudsburg, PA. p. 144



This Flow Diagram is Used to Determine the Relationship of [illegible]
Each of the Igneous Landforms Illustrated in Section 7

7.5.1 Crater, Volcanic/Cone, Volcanic

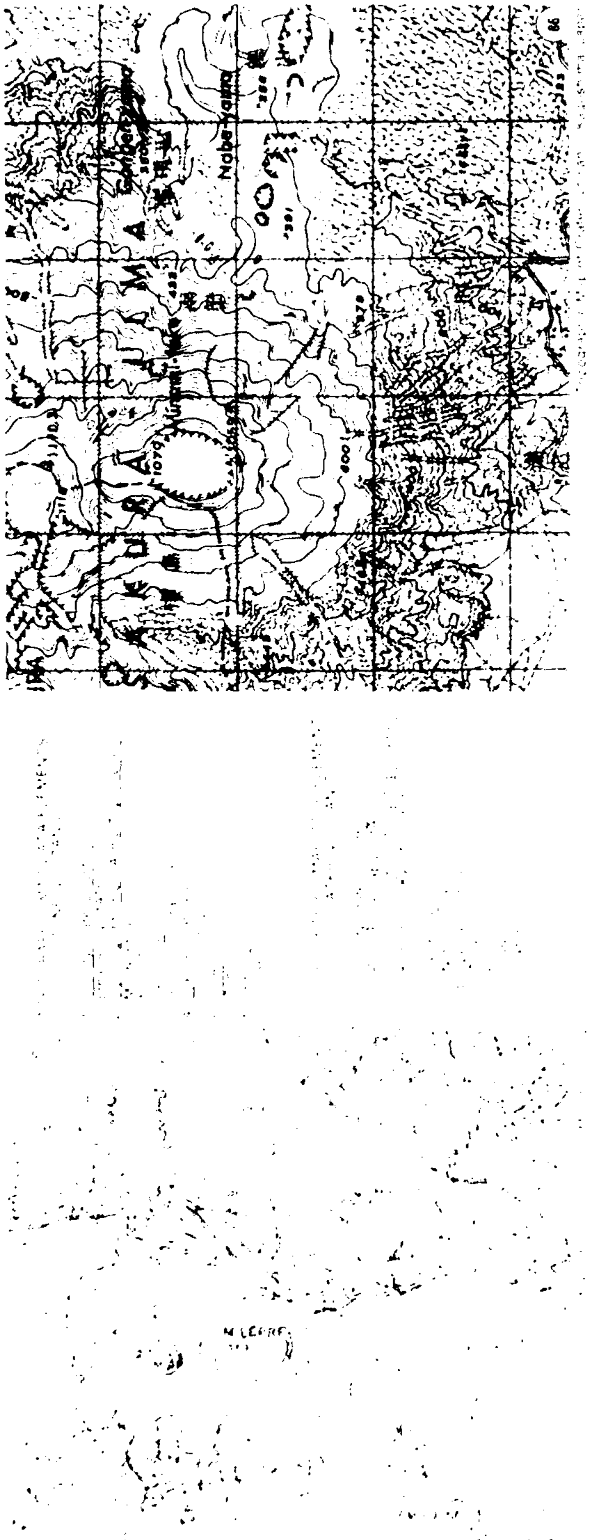

Nobeyama
92
93
94
95

PHOTO PATTERN DATA ELEMENTS CONE VOLCANIC
Photos 53A 4076-4077 (1 25 000) (1955)
Physiography

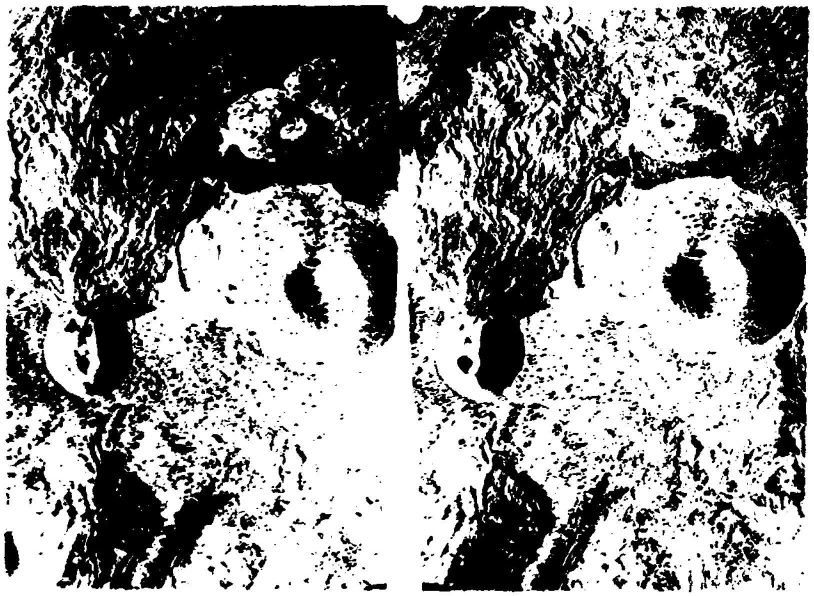
The Apennines — The physiography of this region constitutes the marginal Tyrrhenian block adjacent to a chain of volcanoes and cinder cones including Etna and its associates and the old sunken block relating to the Apennine folds. The volcanic emissions came to the surface along this zone of disturbance. (Dry Subtropic)

ELEMENTS	DESCRIPTORS
Form	Cone formation *circular to oblong* in plan view dish-shaped interior. There is indication of recent lava flows as well as extinct volcanoes
Drainage	Radial drainage pattern
Gully Characteristics	Sag and swell gullies
Special Features	Cone shape
Color (Photo Gray Tones)	On recently active cinder cones a dark tone is noticeable on old cinder cones which have vegetation growing the tone is light
Land Use	Some cultivation of *lower slopes*
Vegetation	*Tree cover* scrub growth

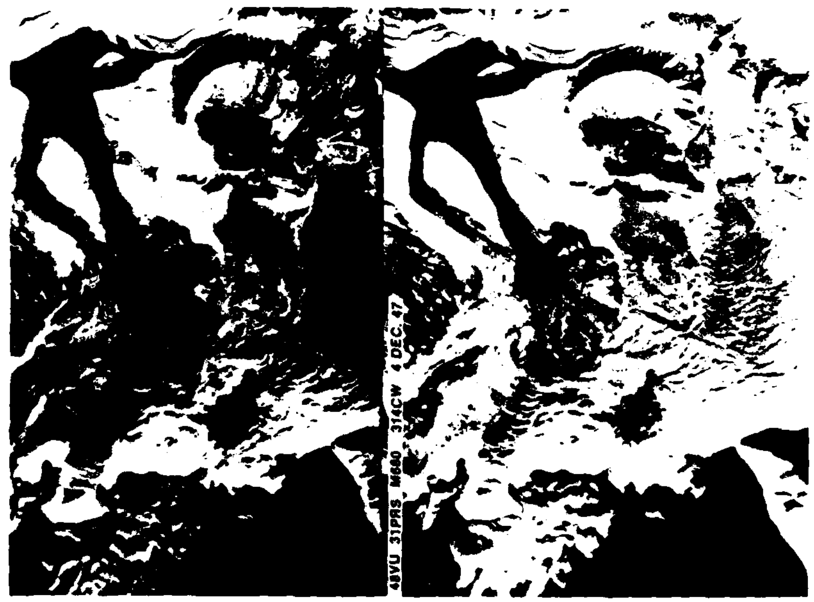
PHOTO PATTERN DATA ELEMENTS CRATER VOLCANIC
Photos JAPAN-7-A B VVM680-47/48. (1947)
Physiography

The Alpine-Himalayan-Island Arc System — This system consists of rocks some as young as the tertiary which were compressed and folded with numerous overthrusts. Earthquakes and volcanoes characterize an extensive belt of landscape forming the Islands of Japan. There are massive blocks within the system, the outer belt of folding and volcanic activity having produced craters in the Japanese Volcanic Chain, the southern arc of this chain has formed Kyushu Island (Wet Subtropic)

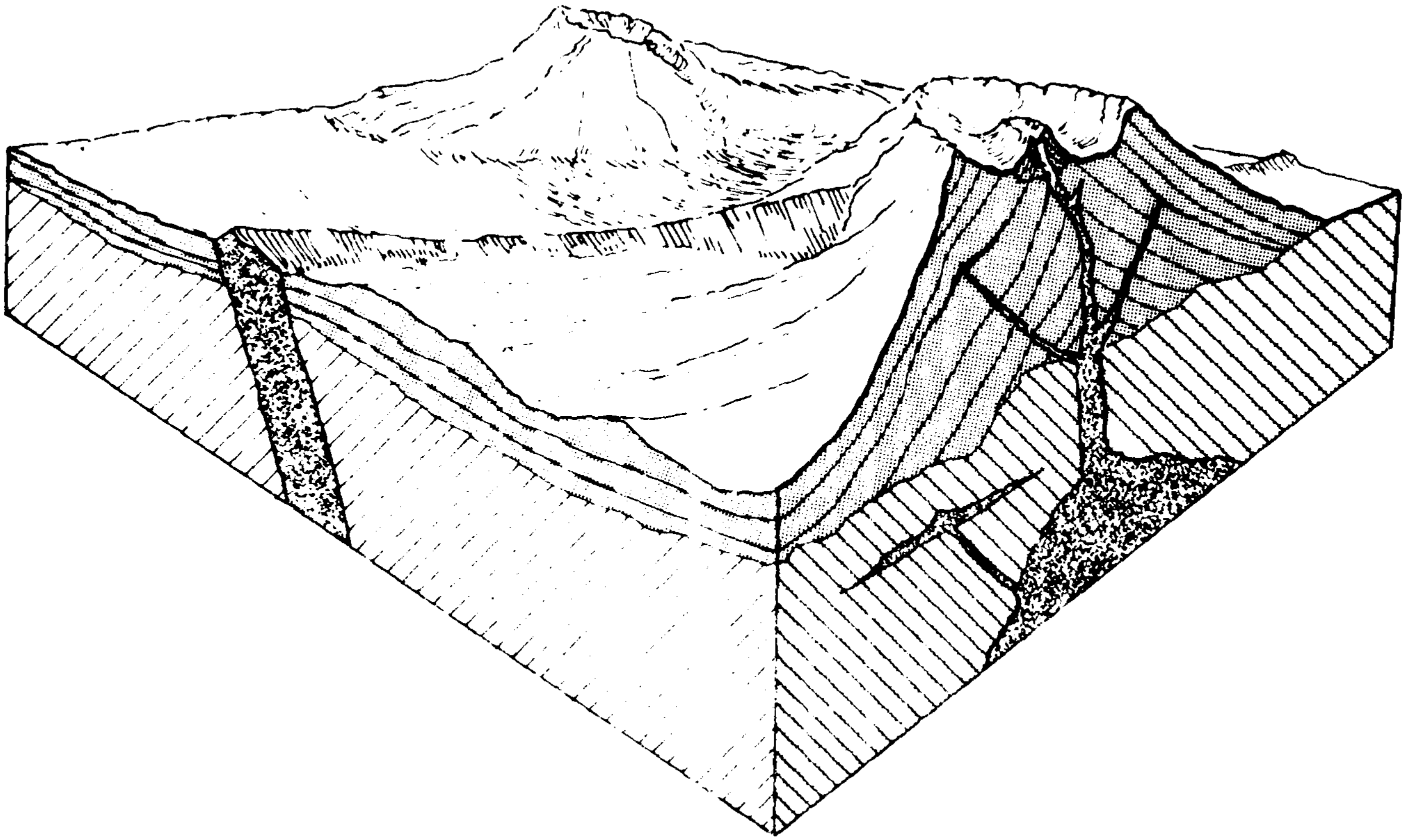
ELEMENTS	*DESCRIPTORS*
Form	Crater sharp knife-edged ridges with the steep slopes of extinct volcano
Drainage	Dendritic, fine to annular
Gully Characteristics	V-shaped
Special Features	*Sharp, knife-edged ridges*
Color (Photo Gray Tones)	Dull, light gray
Land Use	Natural cover forested and grass-covered scrub growth
Vegetation	*Some tree and grass cover in low level zones*



Stereopair of Cone Volcanic



Stereopair of Crater Volcanic



[illegible] Diagram [illegible] Cone

[illegible] Terrain Analysis 1978 [illegible] Stroudsburg PA [illegible] 181

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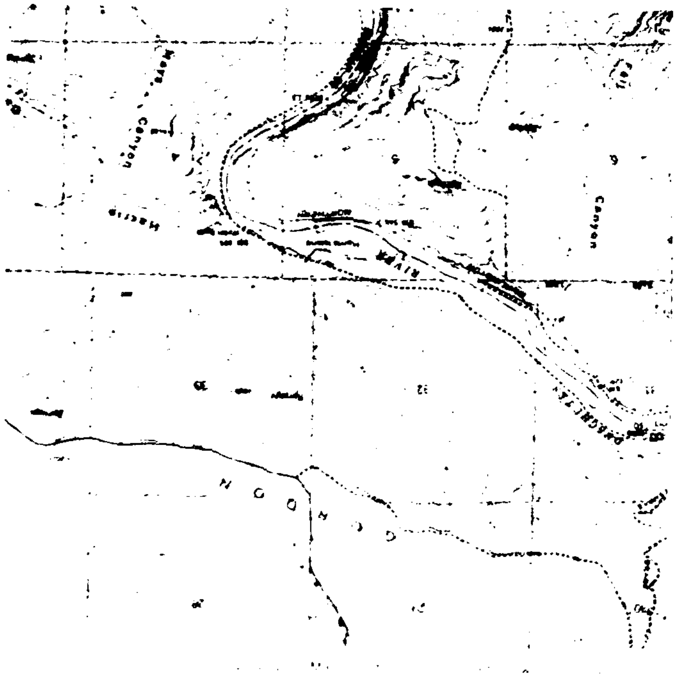
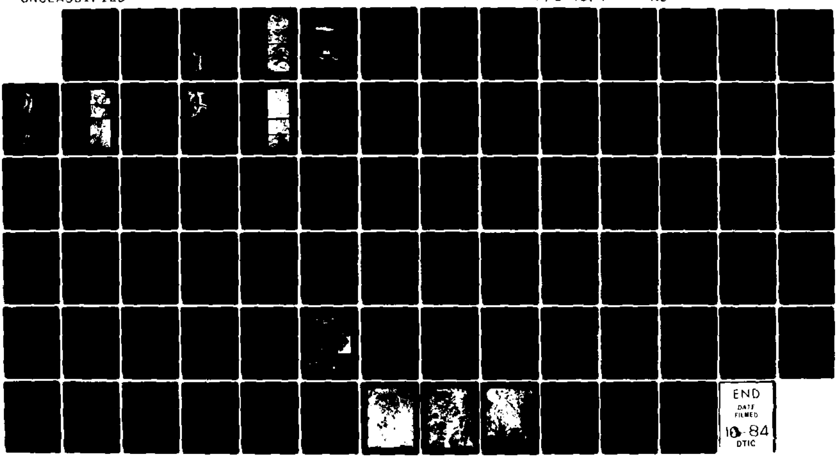
7.5.2 Basalt Flow

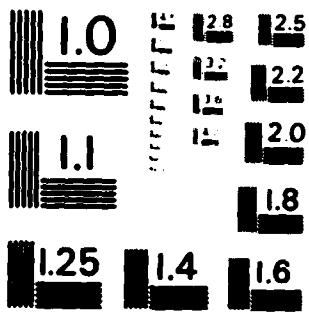

Mays Canyon
Harris
Canyon
RIVER
GORDON

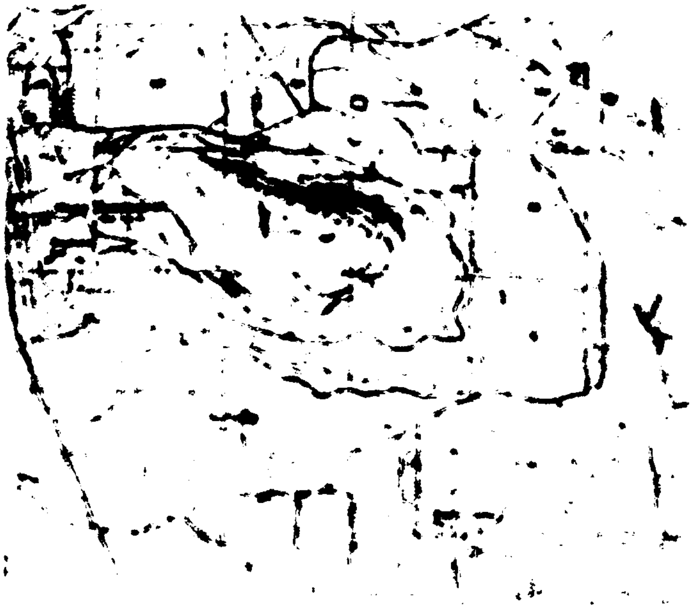

6-3 -65
AAE- 3FF

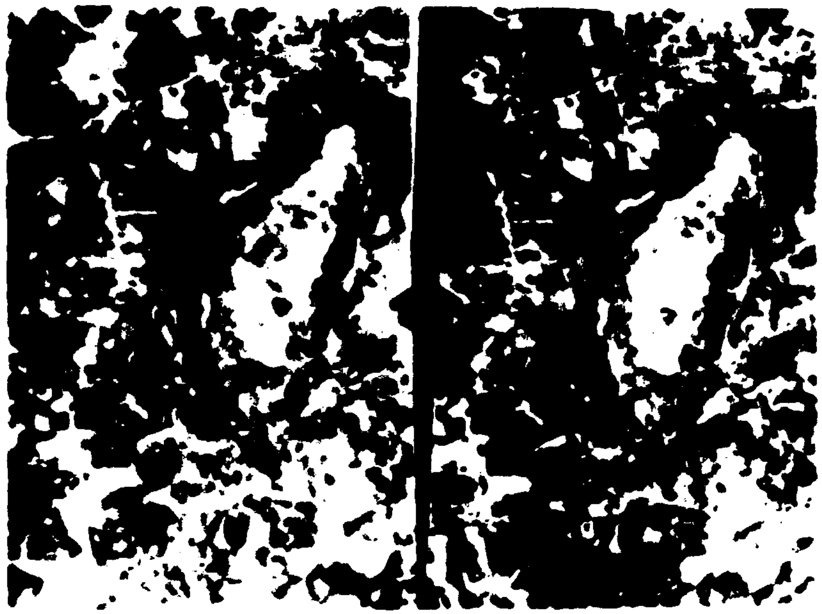
AD-A145 637 TERRAIN ANALYSIS PROCEDURAL GUIDE FOR SURFACE 3/3
CONFIGURATION(U) ARMY ENGINEER TOPOGRAPHIC LABS FORT
BELVOIR VA O MINTZER ET AL. MAR 84 ETL-0352

UNCLASSIFIED F/G 15/4 NL




1.0
2.8
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6





Granite Dome — Surface Roughness of Summit, Stone Mountain, GA

Granite Dome — Surface Roughness of Side-Slope, Stone Mountain, GA

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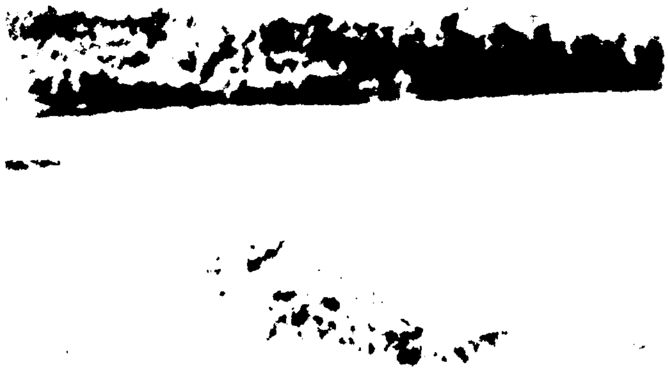

Results of Topographic Map Surface Roughness Measurements: Igneous Forms

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	
[illegible]	[illegible]			[illegible]	
[illegible]					
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[illegible]	[illegible]				
[illegible]	[illegible]			[illegible]	[illegible]

Results of Air Photo Surface Roughness Measurements: Igneous Forms

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]			[illegible]	[illegible]	
[illegible]				[illegible]	
[illegible]					
[illegible]					
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[illegible]

[illegible]	Measurement Method			Average	Sh[illegible]
	[illegible]	Air Photo	Topographic Map		
[illegible]	[illegible]		[illegible]		
[illegible]	[illegible]				
[illegible]	[illegible]				
[illegible]	[illegible]				
[illegible]	[illegible]				

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7.6 Introduction to Metamorphic Rock Forms*

[illegible]

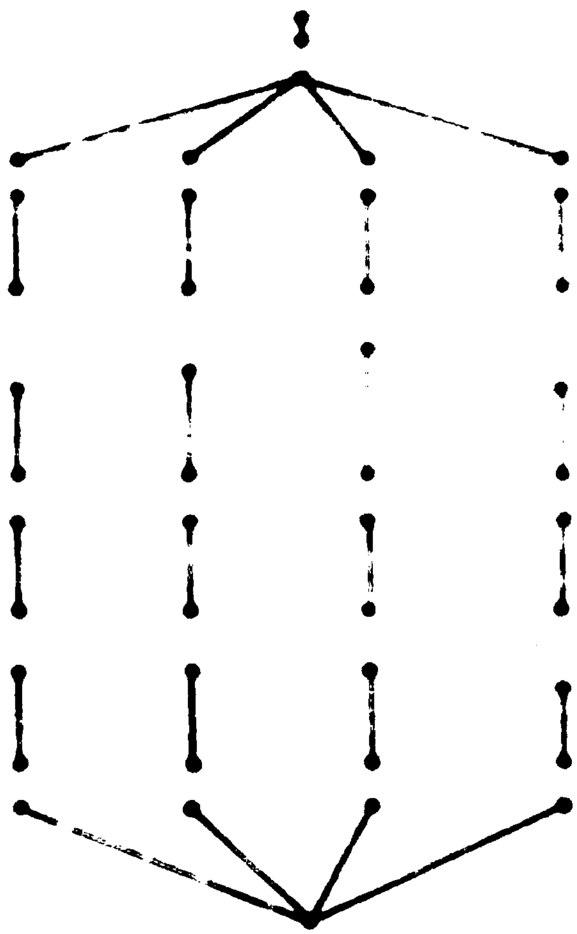
*From Way, D.S., Terrain Analysis, 1978, Dowden, Hutchinson & Ross, Inc., Stroudsburg, PA

Distribution of Major Metamorphic Rock Formations in the United States

Source: [illegible] Terrain Analysis [illegible] Dowden, Hutchinson & Ross, Inc. Stroudsburg, PA, p. [illegible]

World Distribution of Major Metamorphic Rock Formations

Source: [illegible]



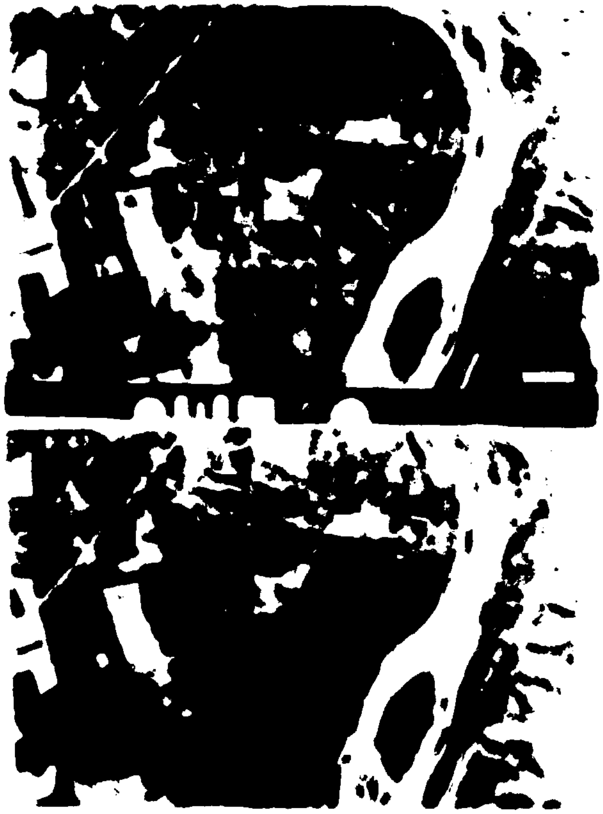


PHOTO PATTERN DATA ELEMENTS: GNEISS
[illegible]
Physiography

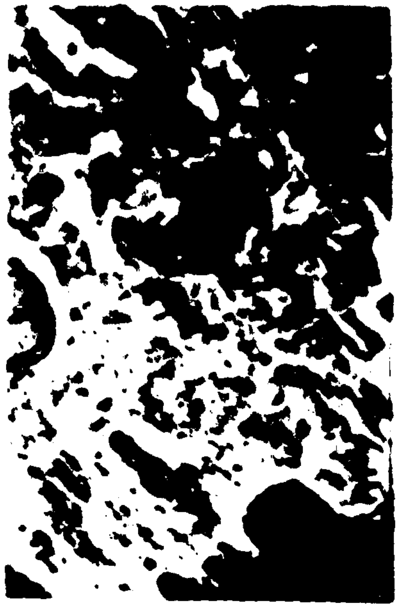
The New England Province [illegible]

ELEMENTS	DESCRIPTIONS
Form	Ridge: moderate to steep rolling topography with parallel ridges [illegible]
Drainage	Angular dendritic, fine to medium
Gully Characteristics	U-shaped
Special Features	Rolling topography with parallel ridges
Color (Photo Gray Tones)	Light gray
Land Use	Agriculture, forest, residential
Vegetation	Forests, agricultural crops, grassland

PHOTO PATTERN DATA ELEMENTS: [illegible]
[illegible]
Physiography

[illegible]

ELEMENTS	DESCRIPTIONS
Form	[illegible]
Drainage	Dendritic, medium
Gully Characteristics	U-shaped
Special Features	[illegible]
Color (Photo Gray Tones)	Light gray
Land Use	[illegible]
Vegetation	[illegible]



[illegible]

[illegible]

[illegible]

Metamorphic Forms

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Contour Spacing (No. [illegible])	[illegible]	[illegible]	[illegible]	[illegible]
Contour Bends (No. [illegible])	[illegible]	[illegible]	[illegible]	[illegible]
Bend Wavelength [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Bend Amplitude [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fencerow Frequency (No. [illegible])	[illegible]	[illegible]	[illegible]	[illegible]
Calculated SR	[illegible]	[illegible]	[illegible]	[illegible]

Results of Air Photo Surface Roughness Measurements: Metamorphic Forms

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Gully Frequency (No. [illegible])	[illegible]	[illegible]	[illegible]	[illegible]
Contour Bends (No. [illegible])	[illegible]	[illegible]	[illegible]	[illegible]
Fencerow Frequency (No. [illegible])	[illegible]	[illegible]	[illegible]	
Point Obstacles (No. [illegible])	[illegible]	[illegible]		[illegible]
Linear Obstacles (No. [illegible])	[illegible]	[illegible]	[illegible]	[illegible]
Tonal Changes (No. [illegible])	[illegible]	[illegible]	[illegible]	[illegible]
Calculated SRI	[illegible]	[illegible]	[illegible]	[illegible]

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[illegible]	Measurement Method			Average	SD
	Estimated	Air Photo	Topographic Map		
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American [illegible] Manual of Photogrammetry [illegible] 1975.

American [illegible] Manual of Photogrammetry [illegible] 1975.

American [illegible] Manual of Photogrammetry [illegible] 1975.

American [illegible] Photogrammetry [illegible] 1968.

American [illegible] Photogrammetry [illegible] Washington [illegible] 1960.

[illegible] Department of [illegible] University [illegible] 1978.

[illegible] *Interpretation of Aerial Photographs* [illegible] Burgess, [illegible]

[illegible] Geology [illegible]

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Belcher, D.J., "The Use of Soil Maps in Highway Engineering, Proceedings of the 28th American Road School," Engineering Bulletin No. 26, Engineering Extension Department, Purdue University, Lafayette, Ind., 1942.

Belcher, D.J., "The Engineering Significance of Soil Patterns," Proceedings of the 23rd Annual Meeting, Highway Research Board, Washington, D.C., 1943.

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[illegible]

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Thompson, [illegible]
Appleton-Century-Crofts, [illegible]

Tricart, J. Landform[illegible]
St. Martin's Press, [illegible]

Verstappen, H. and [illegible]
Surveying." ITC [illegible]
Netherlands, 1968.

[illegible]

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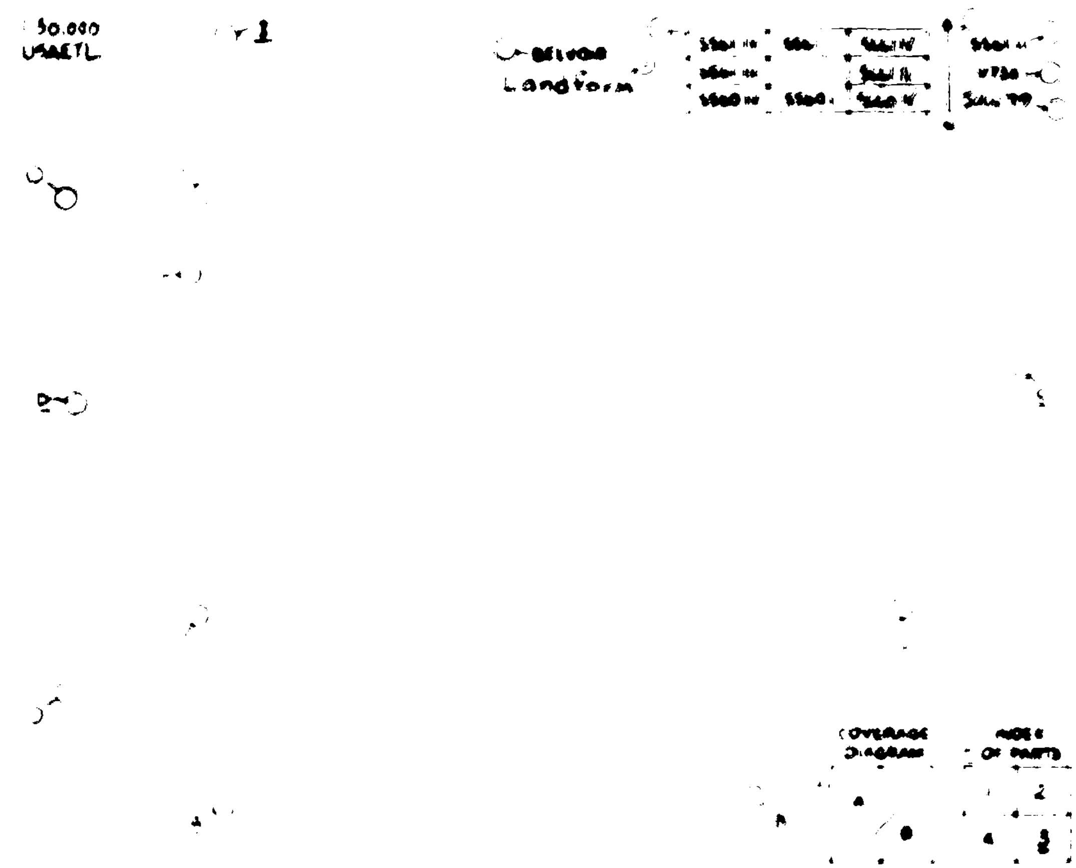
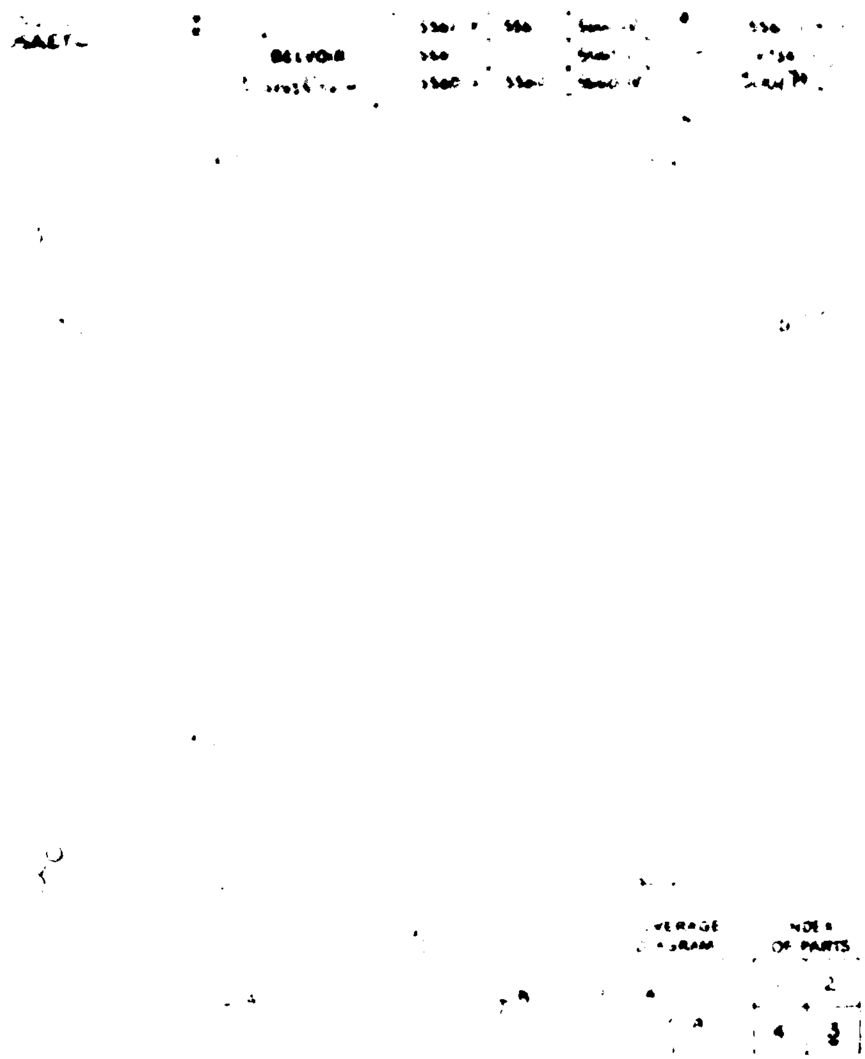

1:50,000
USAETL
BELVOIR
Landform
COVERAGE DIAGRAM
INDEX OF PARTS

Figure A[illegible] [illegible]



[illegible] 52 Format for Factor [illegible] With [illegible] Axis N-S

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] will be [illegible]

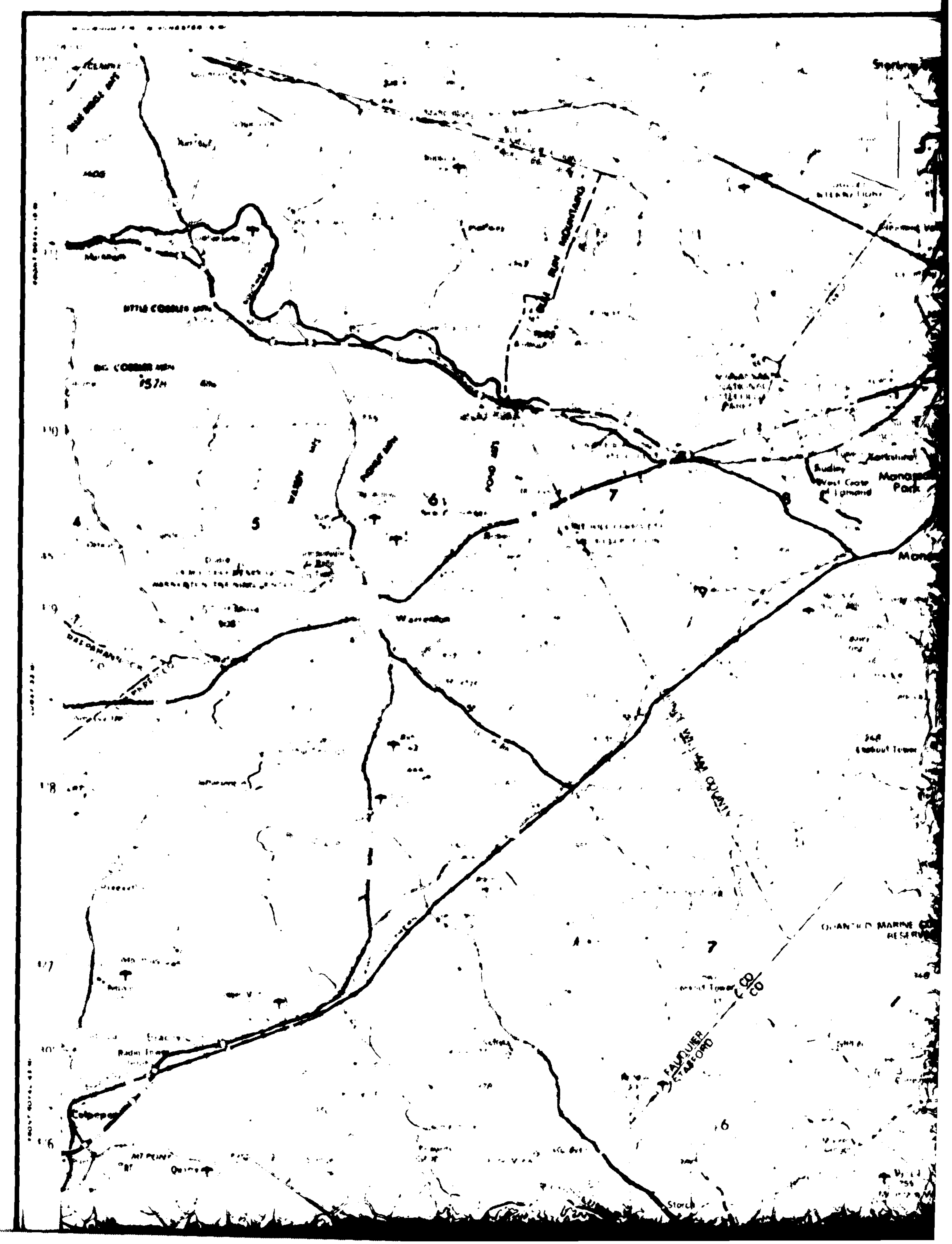
5. All [illegible]

[illegible]

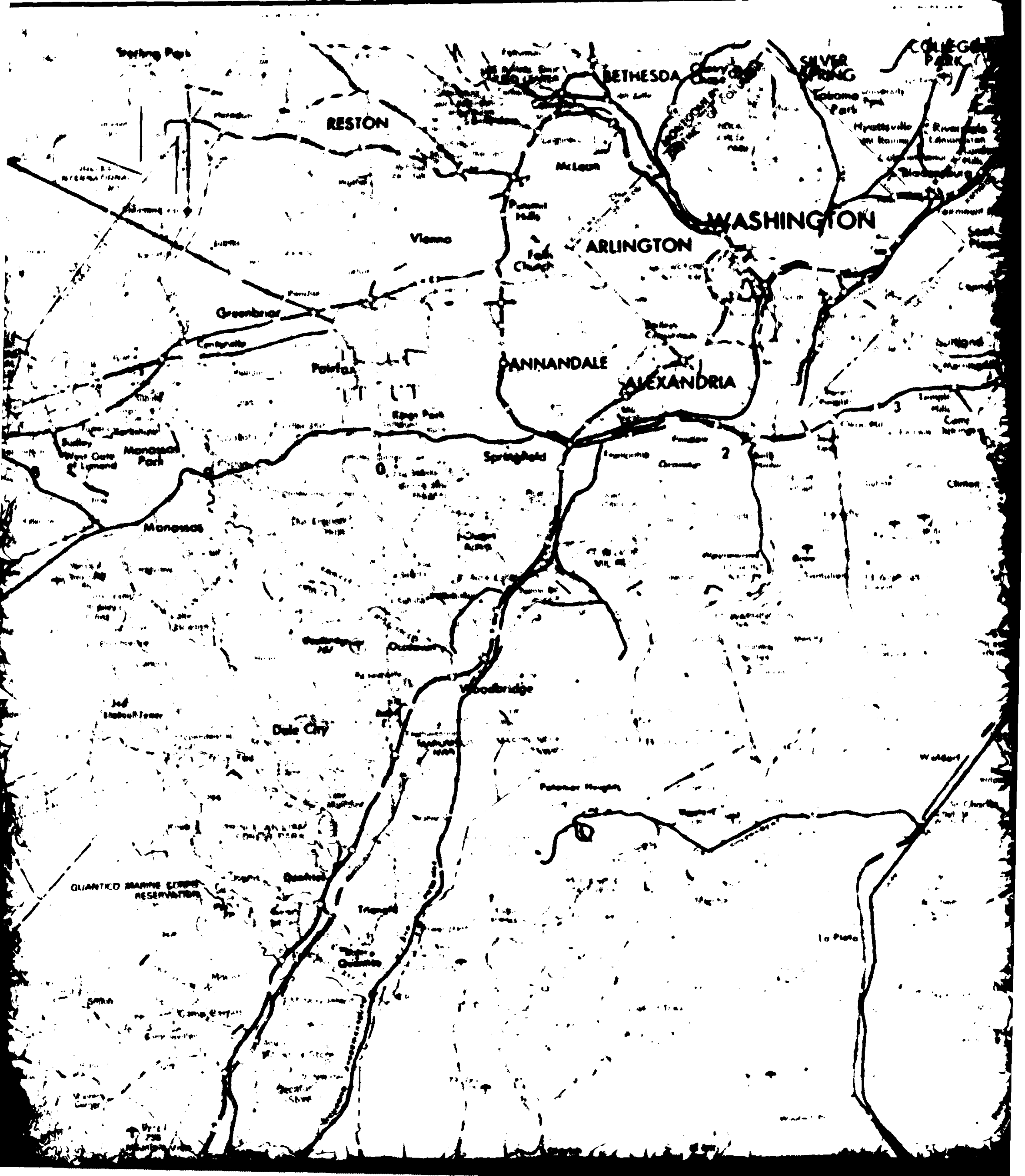
[illegible]

[illegible]

6. [illegible] will be placed [illegible] section [illegible] extend 3 mm from the [illegible] addition of the [illegible]

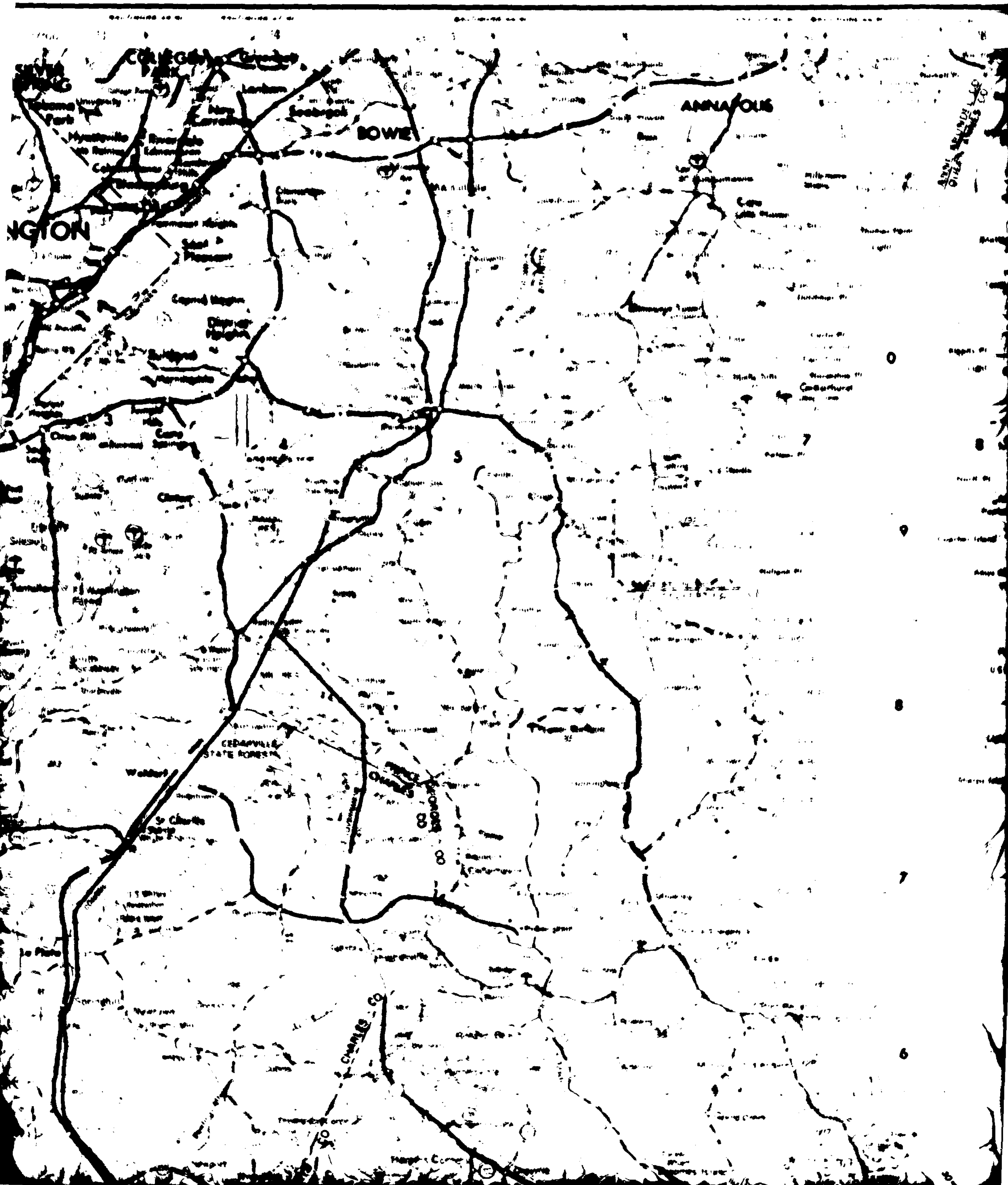

BIG COBBLER MTN
LITTLE COBBLER MTN
BULL RUN MOUNTAINS
Warrenton
Sudley
Lookout Tower
FAUQUIER
STAFFORD
Storch

WASHINGTON

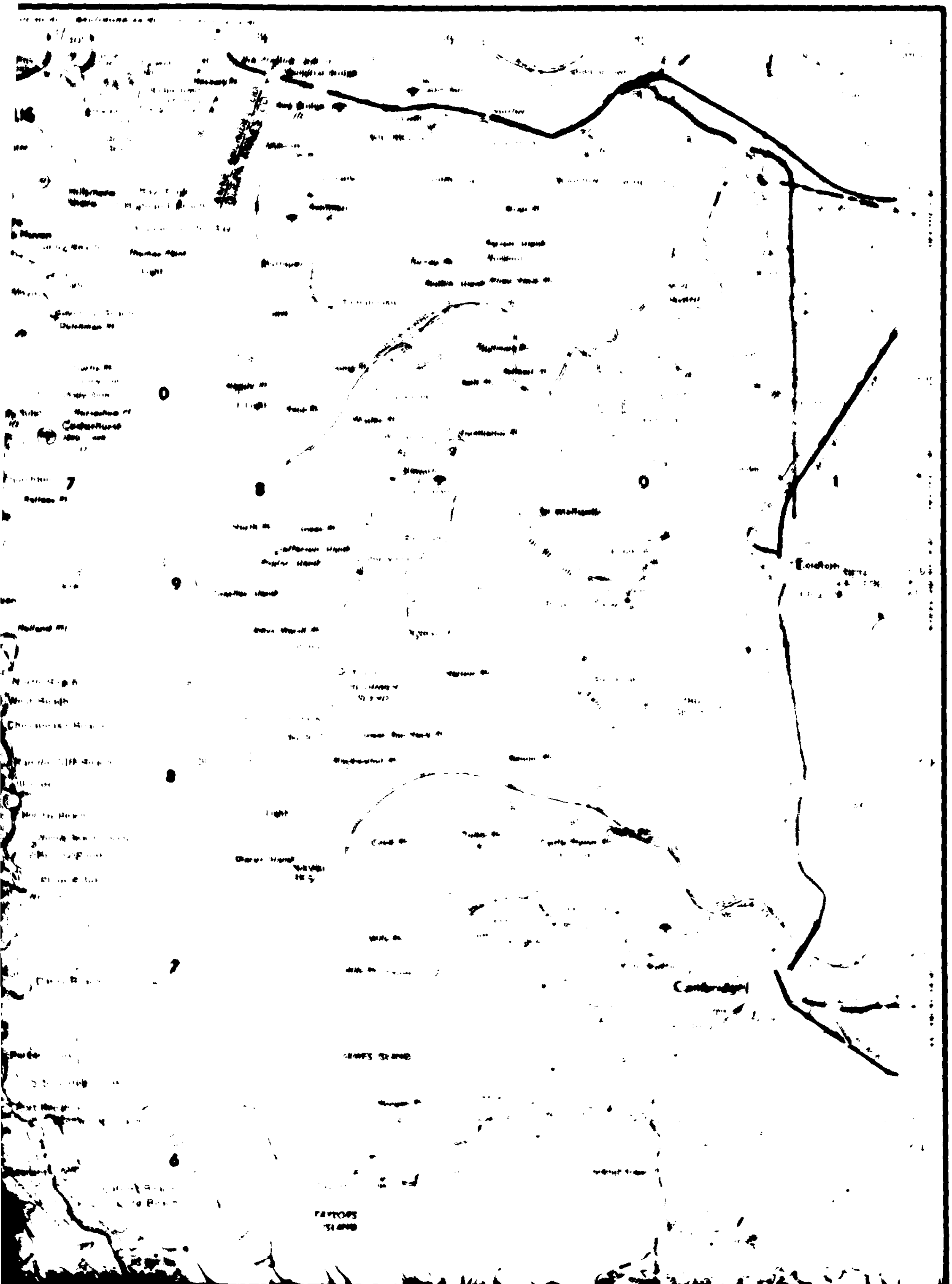


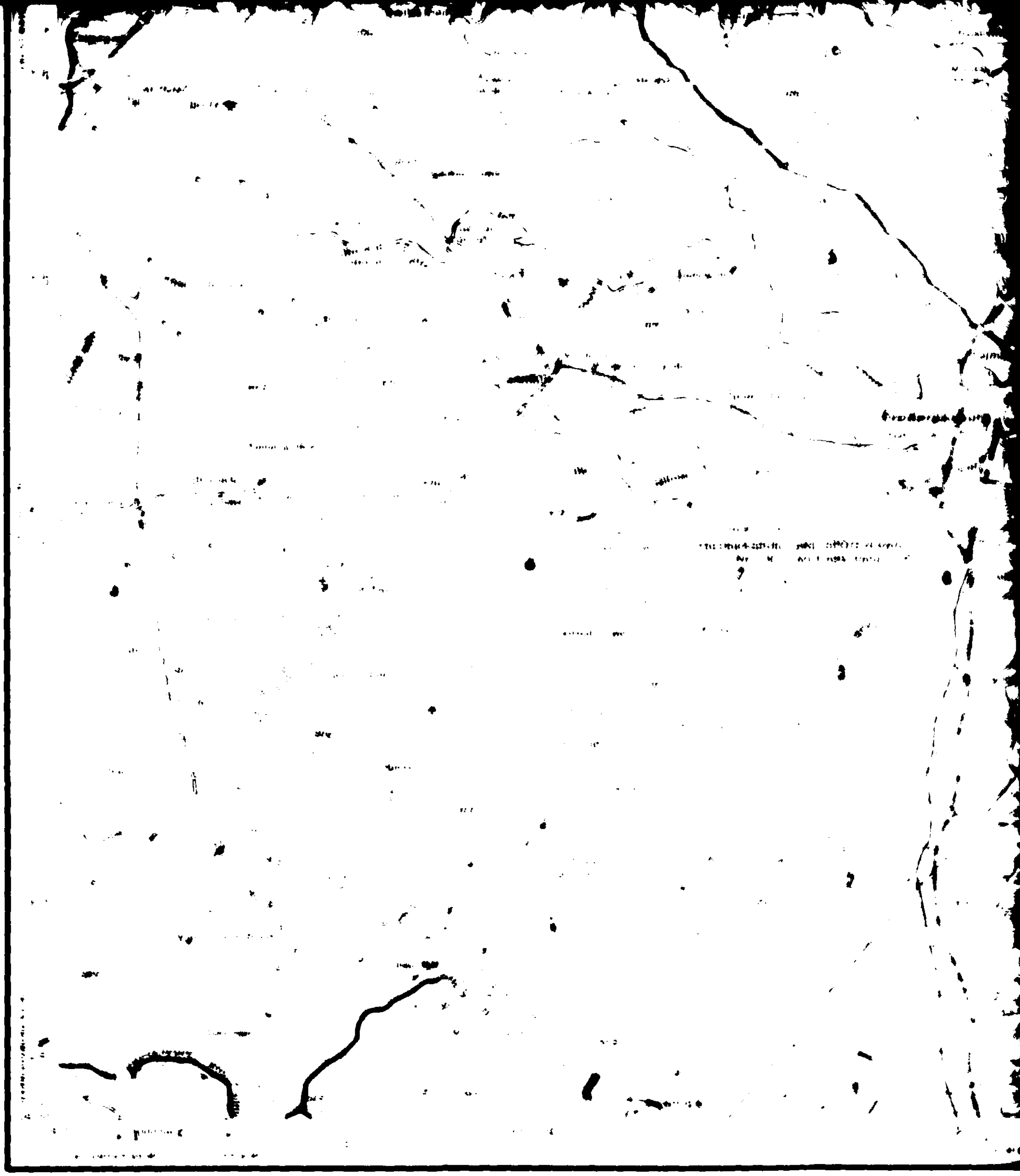
Sterling Park
RESTON
BETHESDA
SILVER SPRING
COLLEGE PARK
Takoma Park
Hyattsville
McLean
WASHINGTON
ARLINGTON
Vienna
Falls Church
Greenbriar
Centreville
Fairfax
ANNANDALE
ALEXANDRIA
Suitland
Springfield
Sudley
Manassas Park
Manassas
Clinton
Woodbridge
Dale City
Potomac Heights
Waldorf
Triangle
QUANTICO MARINE CORPS RESERVATION
La Plata
0
1
2
3

INGTON

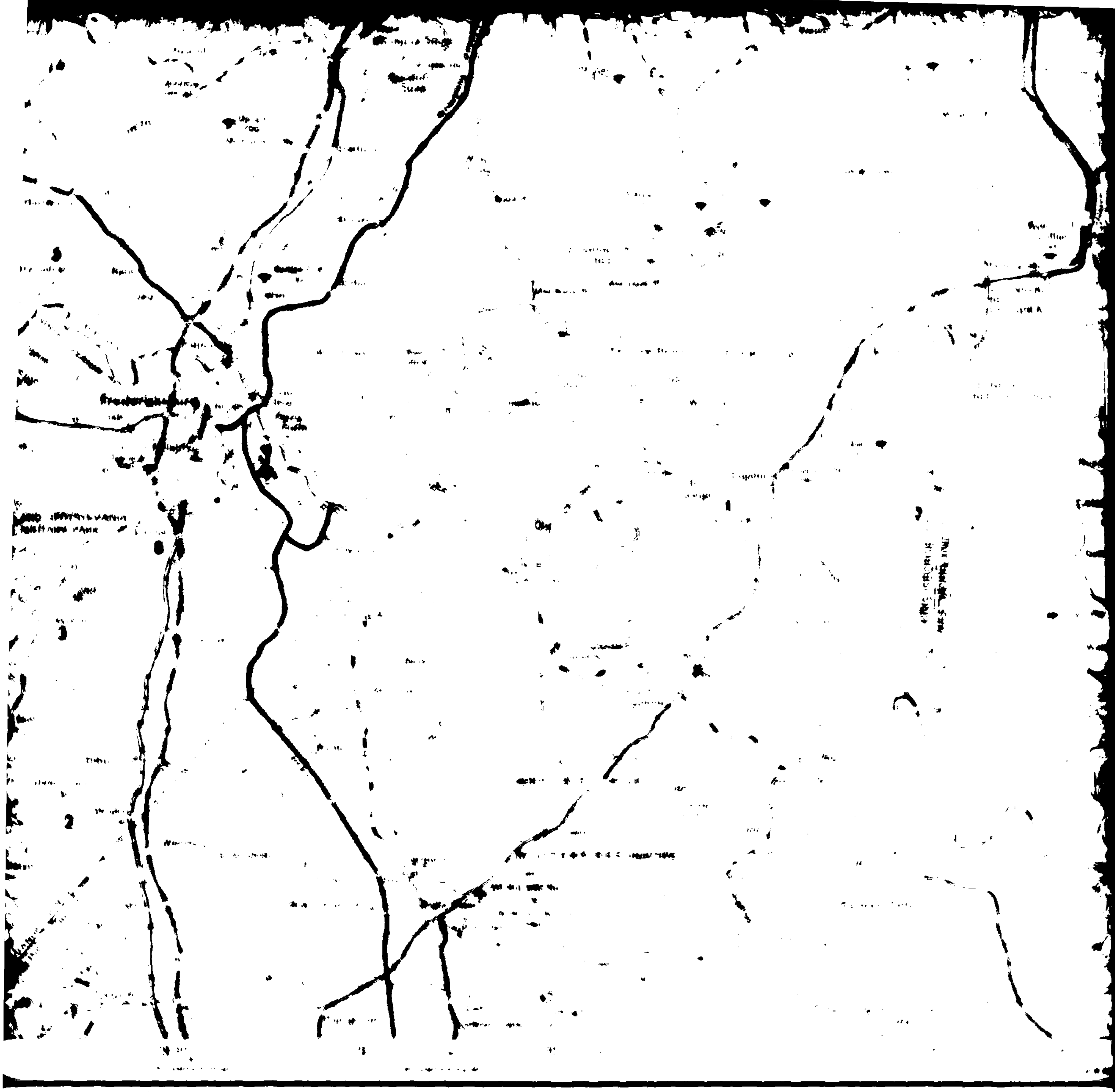


BOWIE
ANNAPOLIS
NGTON
CEDARVILLE
STATE FOREST
PRINCE
CHARLES
Waldorf
St Charles
La Plata
Mount Rainier
Seabrook
Lanham
Capitol Heights
District Heights
Suitland
Clinton
Camp Springs
Pleasant


Cambridge
TAYLORS ISLAND



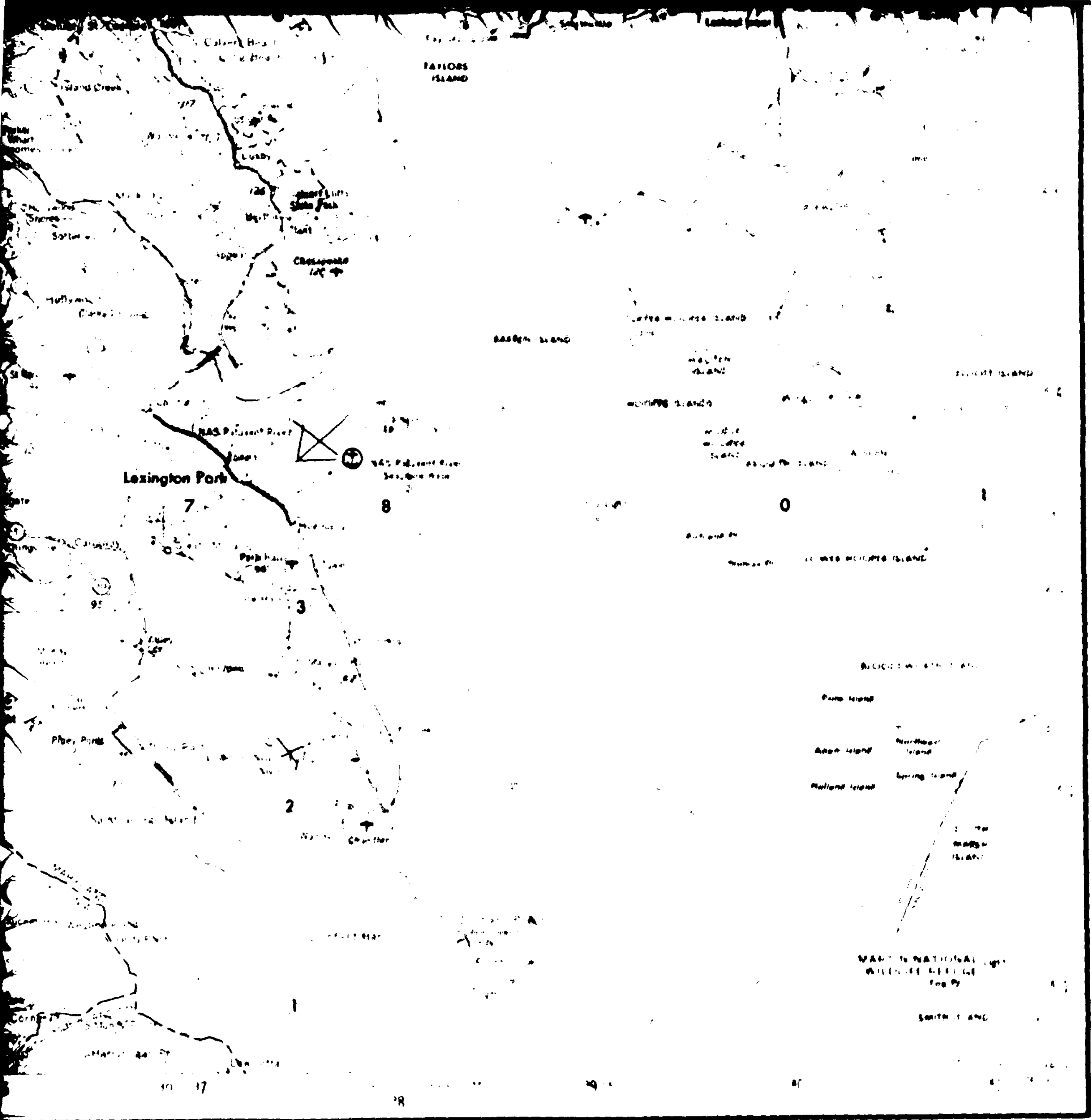
BOSTON

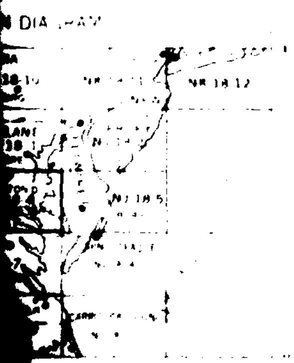


BOSTON
RICHMOND
EVANSTON
Newman

.6

U S





WASHINGTON, D. C., MARYLAND, VIRGINIA

Fairfax County

Organization and Population

Transportation and Markets

Facilities

B2 Geography (Cont.)

Industries

In the county are scientific research laboratories, quarries, gravel pits, distilleries, and sawmills. Agriculture is not a primary source of income. Many people in the county receive most or all of their income from employment in Government offices in the District of Columbia and surrounding areas. Construction is the second most important source of income, followed by public utilities, businesses, and professional and other types of services.

Agriculture

Before this area was settled by white men, the agriculture of the Indians consisted largely of growing small areas of corn. The Indians were chiefly hunters and did little farming. The early pioneers grew corn, wheat, and oats for subsistence and livestock feed. Tobacco was grown as a cash crop for export to England.

The growing of tobacco as a cash crop declined soon after the Civil War. At that time, poultry, cattle, sheep, and hogs became important as sources of cash. Livestock became more important as markets improved and as railroads and highways were constructed. The rapid growth in population of the nearby District of Columbia made the production of milk an important source of income for many farmers in Fairfax County. The production of milk is still an important enterprise in the county. The small acreage that is still used for agriculture is kept in efficient production through the use of scientific methods.

B3 Climate

Climate

Fairfax County has a continental, humid, temperate climate. Temperature and precipitation typical of the county are shown in tables 1 and 2. Seasonal temperature varies considerably. The difference between summer and winter mean temperature at the U.S. Weather Station in Chantilly, Va., is about 36 degrees. It is about 38 degrees at the Washington National Airport, Washington, D.C.

Table 1. Temperature and Precipitation at Chantilly, Fairfax County, Va. (Elevation 320 feet)

[illegible]

Table 2. Temperature and Precipitation at Washington National Airport, Washington, D.C. (Elevation 14 feet)

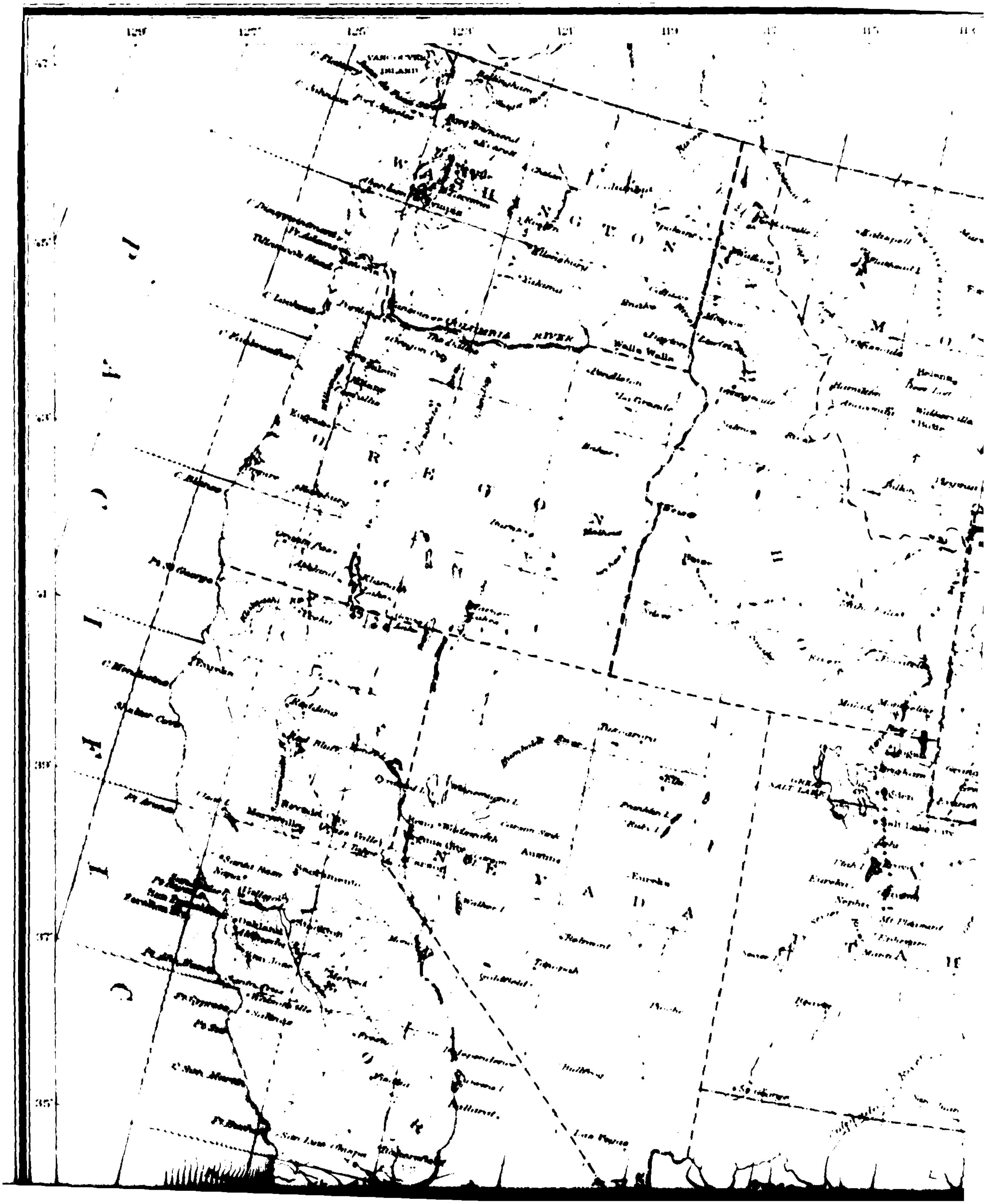
[illegible]

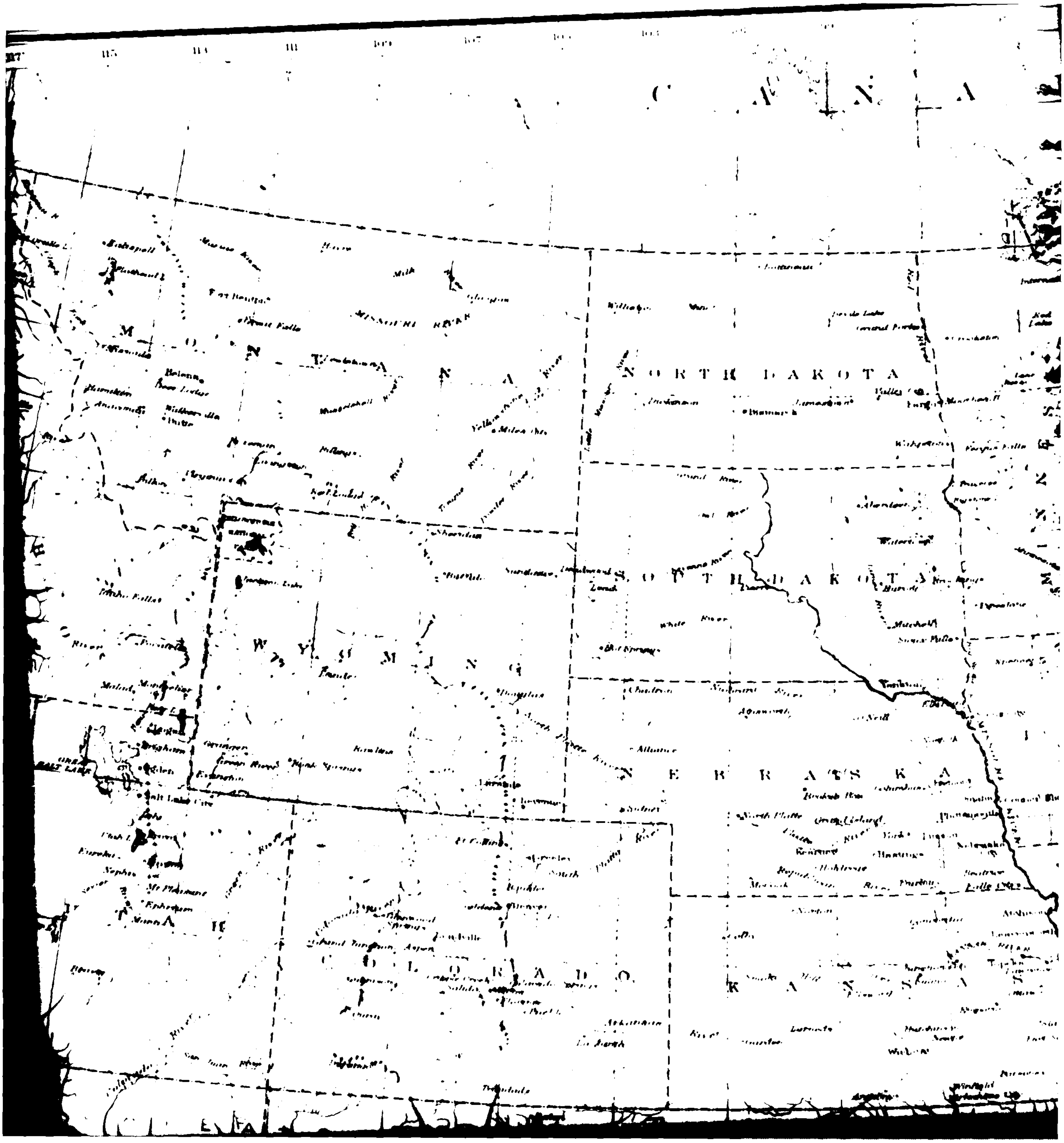
B3 Climate (Cont.)

The frost-free season at Chantilly, Va., is 175 days; in Washington, D.C., it is 200 days. The frost-free season generally is long enough for the maturing of the field crops and vegetables commonly grown in Fairfax County. The ground is frozen only to shallow depths during winter. Some snow falls in the winter, but it stays on the ground for only a short time. Many cover crops can be grown. Outdoor work can be performed all winter except during a few unusually cold periods.

The grazing season is about 220 days. It begins in the middle of April and extends to the middle of November. Some well-managed pastures on favorable soils can be grazed from the first of April to the first of December.

Rainfall is generally ample for most crops, except in dry years. Most rain falls in the summer and spring. Crops planted late in wet springs are sometimes damaged by early fall frost before they mature. This occurs on some of the moderately well drained and somewhat poorly drained Calverton, Readington, Beltsville, and Iredell soils. There are no mountains in the county. Consequently, differences in the suitability of soils for crops are due to factors other than climate.

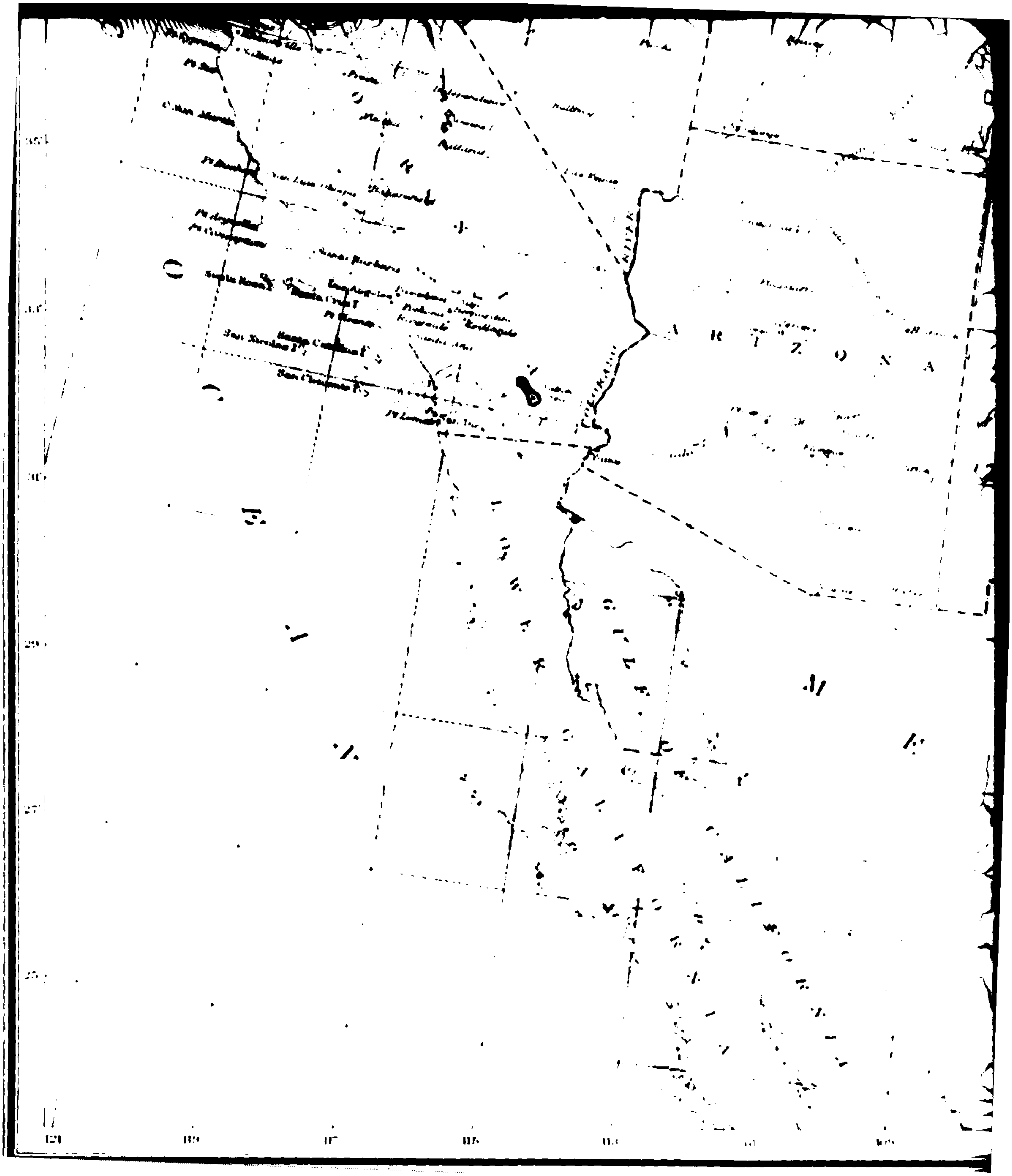

Walla Walla
Eureka

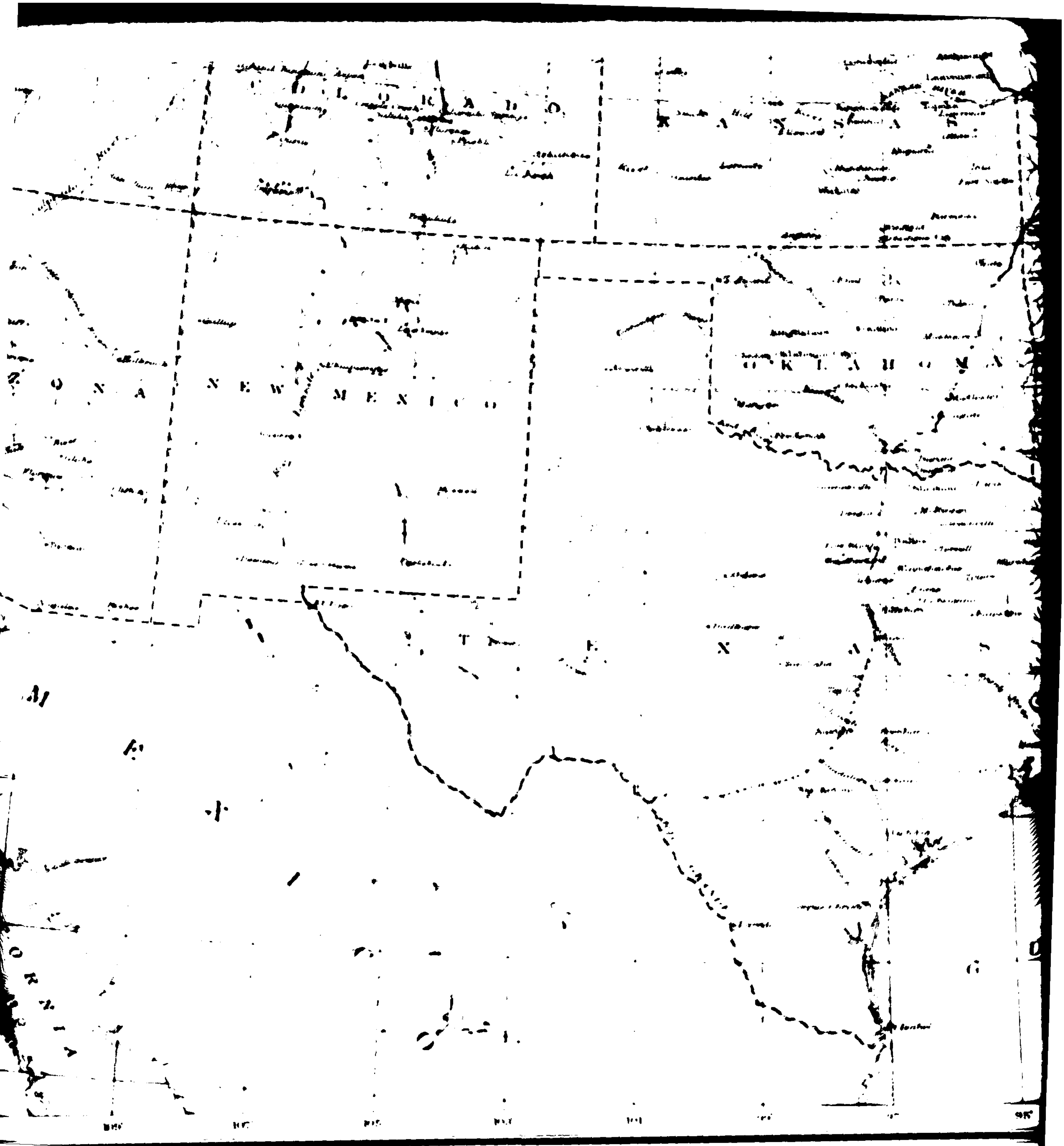


NORTH DAKOTA
SOUTH DAKOTA
WYOMING
NEBRASKA
COLORADO
KANSAS
Helena
Bismarck
Jamestown
Mitchell
Sioux Falls
Yankton
Alliance
North Platte
Grand Island
Laramie
Leadville
Aspen
Trinidad
Salt Lake City
Brigham
Logan

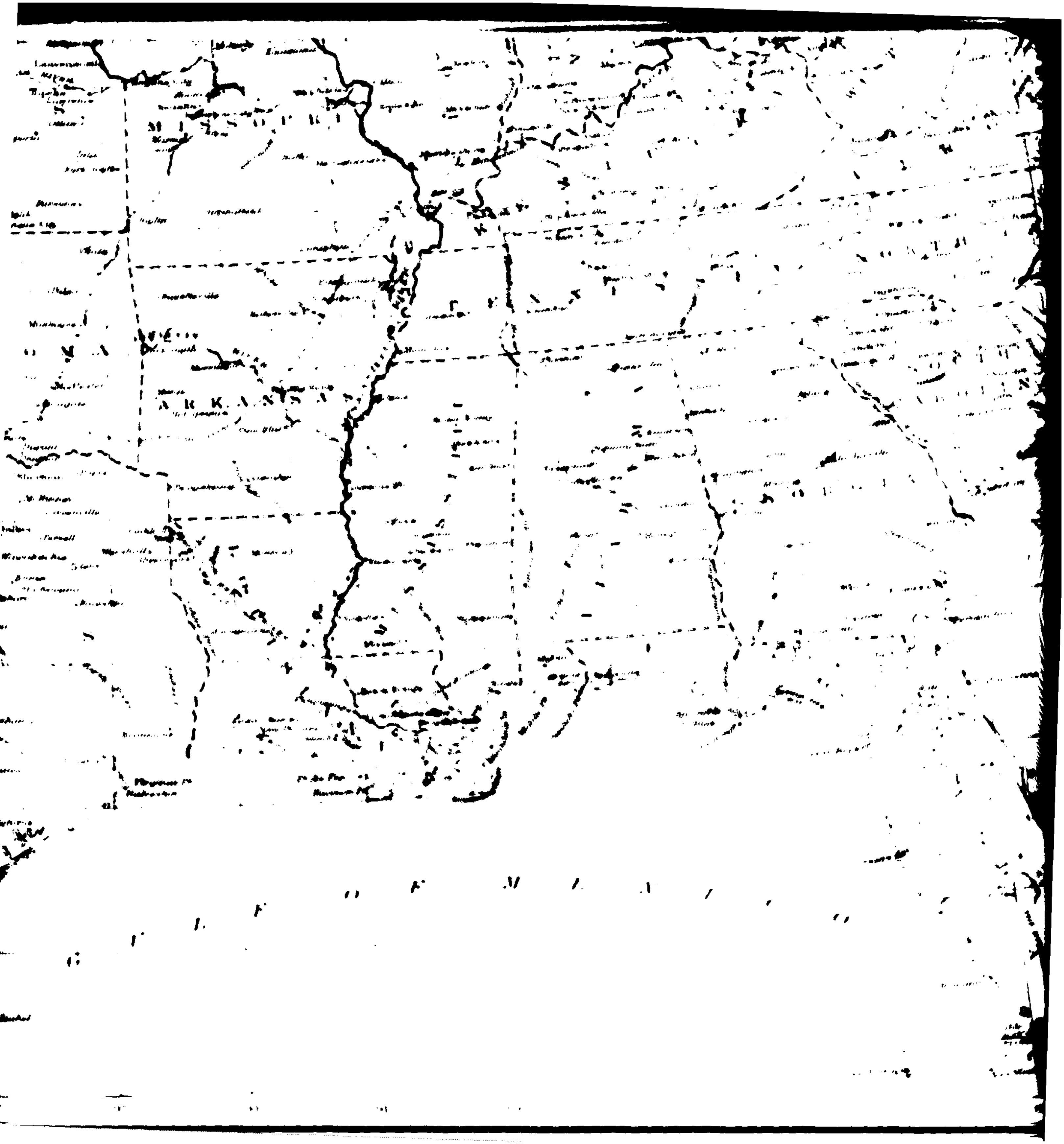

Grand Forks
International Falls
Fergus Falls
Little Falls
St Cloud
Stillwater
Sioux Falls
Sioux City
Hastings
York
Lincoln
Atchison
Topeka

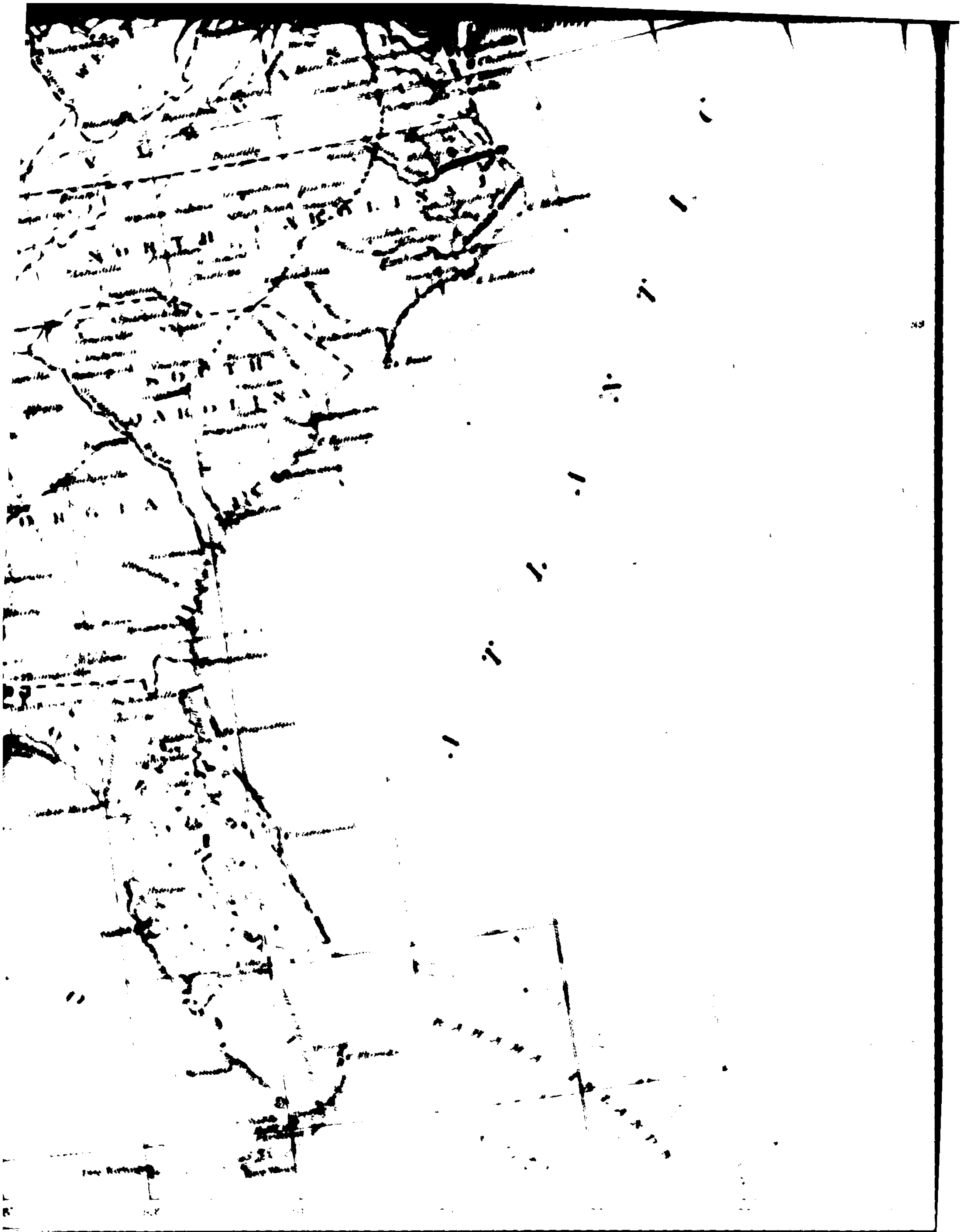

LAKE ONTARIO
PENNSYLVANIA
Boston
Nantucket
Long Branch
Barnegat Inlet
Atlantic City
C Hatteras

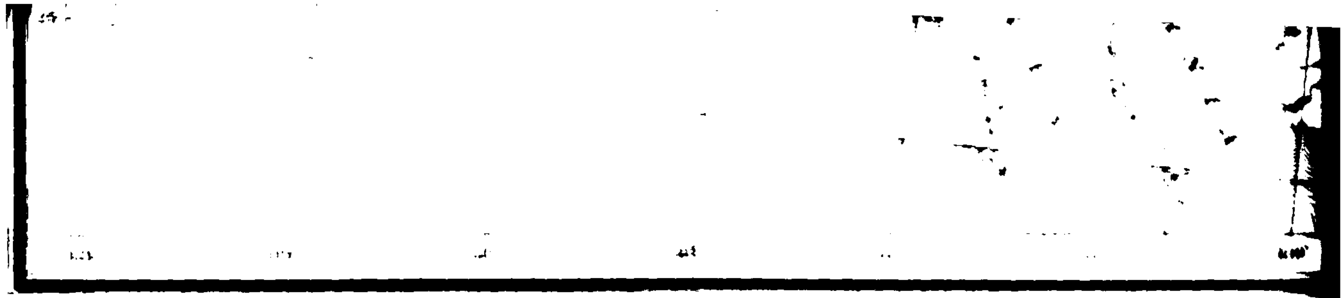

A R I Z O N A
COLORADO
RIVER
Santa Barbara
San Nicolas I.
San Clemente I.
121
119
117
115
113
111
109



N E W   M E X I C O
O K L A H O M A







MAJOR DIVISION	PROVINCE	SECTION	CHARACTERISTICS
Laurentian Upland	1. Superior Upland		1. Submaturely dissected [illegible] peneplaned gn… complex structure
	2. Continental Shelf		2. Submerged coastal plain [illegible]
Atlantic Plain	3. Coastal Plain	a. Embayed section	3a. Submaturely dissected [illegible] partly submerged…
		b. Sea Island section	3b. Young to mature terraced coastal plain with…
		c. Floridian section	3c. Young marine plain [illegible] swamps…
		d. East Gulf Coastal Plain	3d. Young to mature belted coastal plain
		e. Mississippi Alluvial Plain	3e. Flood plain and delta
		f. West Gulf Coastal Plain	3f. Young grading inland to mature coastal plain
Appalachian Highlands	4. Piedmont province	a. Piedmont Upland	4a. Submaturely dissected peneplain on disordered… strata…
		b. Piedmont Lowlands	4b. Less uplifted peneplain on weak strata…
	5. Blue Ridge province	a. Northern section	5a. Mature dissected mountains of crystalline…
		b. Southern section	5b. Subdued mountains of disordered crystalline…
	6. Valley and Ridge province	a. Tennessee section	6a. Second-cycle mountains of folded strong and… predominate over even crested ridges
		b. Middle section	6b. The same but even crested ridges predominate… larger scale
		c. Hudson Valley	6c. Glaciated [illegible] folded strata
	7. St. Lawrence Valley	a. Champlain section	7a. Rolling lowland [illegible] covered by…
		b. Northern section	7b. Young marine plain [illegible]
	8. Appalachian Plateaus	a. Mohawk section	8a. Maturely dissected [illegible] varied…
		b. Catskill section	8b. Maturely dissected plateau of mountainous… glaciated
		c. Southern New York section	8c. Mature glaciated plateau of moderate relief
		d. Allegheny Mountain section	8d. Mature plateau of strong relief; some… folds
		e. Kanawha section	8e. Mature plateau of fine texture, moderate to…
		f. Cumberland Plateau section	8f. Submaturely dissected plateau of moderate…
		g. Cumberland Mountain section	8g. Higher mature plateau and mountain ridges…
	9. New England province	a. Seaboard Lowland section	9a. Peneplane below 500 feet, monadnocks… rocks
		b. New England Upland section	9b. Dissected and glaciated peneplain on complex… rocks
		c. White Mountain section	9c. Subdued glaciated mountain masses of crystal…
		d. Green Mountain section	9d. Linear ranges of subdued and glaciated moun…
		e. Taconic section	9e. Maturely dissected and glaciated mountains… folded strata
	10. Adirondack province		10. Subdued mountains and dissected peneplain…

4

CHARACTERISTICS	MAJOR DIVISION	PROVINCE	SECTION	
[illegible]ly dissected [illegible] structure			a. Highland Rim section	11a.
[illegible] submature plain of [illegible]		11. Interior Low Plateaus	b. Lexington Plain	11b.
[illegible]ly dissected and partly [illegible]			c. Nashville Basin	11c.
[illegible] mature terraced coastal plain [illegible]			d. Possible western section (not delimited)	11d.
[illegible]marine plain with sand hills [illegible]			a. Eastern lake section	12a.
[illegible] mature buried coastal plain			b. Western lake section	12b.
[illegible]ain and delta		12. Central Lowland	c. Wisconsin Driftless section	12c
[illegible]ing inland to mature coastal plain			d. Till Plains	12d.
[illegible]ly dissected peneplain on [illegible] rocks; moderate [illegible]	Interior Plains		e. Dissected Till Plains	12e
[illegible]ed peneplain on weak strata; residual ridges on strong rocks			f. Osage Plains	12f
[illegible] dissected mountains of crystalline rocks; accordant altitudes			a. Missouri Plateau, glaciated	13a.
[illegible] mountains of discordant crystalline rocks			b. Missouri Plateau, unglaciated	13b.
[illegible]cycle mountains of folded strong and weak strata; valley belts [illegible]dominate over even crested ridges			c. Black Hills	13c.
[illegible]; but even crested ridges predominate over valleys except on [illegible] side			d. High Plains	13d
[illegible] peneplain on weak folded strata		13. Great Plains province	e. Plains Border	13e.
[illegible] lowland glaciated in part covered by young marine plain			f. Colorado Piedmont	13f
[illegible]marine plain with local rock hills			g. Raton section	13g
[illegible] dissected glaciated plateau; varied relief and [illegible] altitudes			h. Pecos Valley	13h
[illegible] dissected plateau of mountainous relief and [illegible] texture [illegible]			i. Edwards Plateau	13i
[illegible]glaciated plateau of moderate relief			k. Central Texas section	13k
[illegible] plateau of strong relief; some mountains due to erosion of open [illegible]		14. Ozark Plateaus	a. Springfield-Salem plateaus	14a.
[illegible] plateau of fine texture; moderate to strong relief	Interior Highlands		b. Boston "Mountains"	14b
[illegible]ly dissected plateau of moderate to strong relief		15. Ouachita province	a. Arkansas Valley	15a.
[illegible]ature plateau and mountain ridges on eroded open folds			b. Ouachita Mountains	15b.
[illegible] below 700 feet postmaturely eroded and glaciated; few monad[illegible]		16. Southern Rocky Mountains		16.
[illegible] and glaciated peneplains on complex structural features; monad[illegible]	Rocky Mountain System	17. Wyoming Basin		17
[illegible] glaciated mountain masses of crystalline rocks		18. Middle Rocky Mountains		18
[illegible] of subdued and glaciated mountains and residual plateaus		19. Northern Rocky Mountains		19
[illegible] dissected and glaciated mountains and peneplain on resistant [illegible] strata				
[illegible] mountains and dissected peneplain; glaciated				

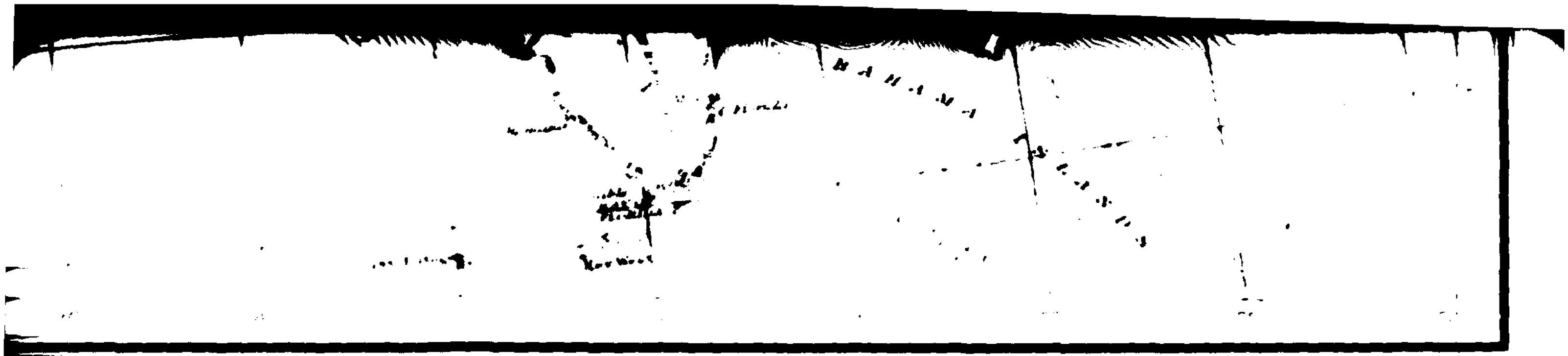
*Prepared by Nevin M. Fenneman and [illegible]

*Degrees of relief are herein spoken of as [illegible]
As used here *high* relief is measured in t[illegible]
in hundreds of feet. *Strong* relief may b[illegible]
with a wide latitude on both sides.

SECTION		CHARACTERISTICS	MAJOR DIVISION	PROVINCE
ighland Rim section	11a	Young to mature plateau of moderate relief		
exington Plain	11b	Mature to old plain on weak rocks; trenched by main rivers		
ashville Basin	11c	Mature to old plain on weak rocks; slightly uplifted and moderately dissected		20 Columbia Plateau
ossible western section (not delimited)	11d	Low, maturely dissected plateau with silt filled valleys		
astern lake section	12a	Maturely dissected and glaciated cuestas and lowlands; moraines, lakes and lacustrine plains		
estern lake section	12b	Young glaciated plain; moraines, lakes and lacustrine plains		
isconsin Driftless section	12c	Maturely dissected plateau and lowland invaded by glacial outwash (Margin of old eroded drift included)		
ill Plains	12d	Young till plains; morainic topography rare; no lakes		21 Colorado Plateaus
issected Till Plains	12e	Submaturely to maturely dissected till plains	Intermontane Plateaus	
sage Plains	12f	Old scarped plains beveling faintly inclined strata; main streams in trenched		
issouri Plateau, glaciated	13a	Glaciated old plateaus; isolated mountains		
issouri Plateau, unglaciated	13b	Old plateau; terrace lands; local badlands; isolated mountains		
ack Hills	13c	Maturely dissected domed mountains		
igh Plains	13d	Broad intervalley remnants of smooth fluviatile plains		22 Basin and Range province
lains Border	13e	Submaturely to maturely dissected plateau		
olorado Piedmont	13f	Late mature to old elevated plain		
aton section	13g	Trenched peneplain surmounted by dissected, lava capped plateaus and buttes		
ecos Valley	13h	Late mature to old plain		23 Cascade-Sierra Mountains
dwards Plateau	13i	Young plateau with mature margin of moderate to strong relief		
entral Texas section	13k	Plateau in maturity and later stages of erosion		
ringfield-Salem plateaus	14a	Submature to mature plateaus		
oston "Mountains"	14b	Submature to mature plateau of strong relief		
kansas Valley	15a	Gently folded strong and weak strata; peneplain with residual ridges	Pacific Mountain System	
achita Mountains	15b	Second-cycle mountains of folded strong and weak strata		24 Pacific Border province
	16	Complex mountains of various types; intermont basins		
	17	Elevated plains in various stages of erosion; isolated low mountains		
	18	Complex mountains, mainly anticlinal ranges; intermont basins		
	19	Deeply dissected mountain uplands, not anticlinal ranges; intermont basins		25 Lower Californian province

d by Nevin M. Fenneman and Douglas W. Johnson
of relief are herein spoken of as low, moderate, strong, and high
re *high* relief is measured in thousands of feet, *moderate* relief
of feet. *Strong* relief may be anything approaching 1,000 feet
latitude on both sides

11



MAJOR DIVISION	PROVINCE	SECTION	CHARACTERISTICS
		a Walla Walla Plateau	20a Rolling plateau with young incised valleys
		b Blue Mountain section	20b Complex mountains and dissected volcanic plateaus
	20 Columbia Plateaus	c Payette section	20c Young plateaus of prevailingly weak rocks; broad alluvial terraces. Applies to northern part only
		d Snake River Plain	20d Young lava plateau
		e Harney section	20e Young lava plateau; features of recent volcanism; ineffective drainage
		a High Plateaus of Utah	21a High block plateaus, in part lava capped; terraced plateaus on south side
		b Uinta Basin	21b Dissected plateau, strong relief
...ntane ...us	21 Colorado Plateaus	c Canyon Lands	21c Young to mature canyoned plateaus; high relief
		d Navajo section	21d Young plateaus; smaller relief than 21c, into which it grades
		e Grand Canyon section	21e High block plateaus, trenched by Grand Canyon
		f Datil section	21f Lava flows entire or in remnants; volcanic necks
		a Great Basin	22a Isolated ranges, largely dissected block mountains, separated by aggraded desert plains
	22 Basin and Range province	b Sonoran Desert	22b Widely separated short ranges in desert plains
		c Salton Trough	22c Desert alluvial slopes and delta plain. Gulf of California
		d Mexican Highland	22d Isolated ranges, largely dissected block mountains, separated by aggraded desert plains
		e Sacramento section	22e Mature block mountains of gently tilted strata; block plateaus; bolsons
		a Northern Cascade Mountains	23a Sharp alpine summits of accordant height; higher volcanic cones
	23 Cascade-Sierra Mountains	b Middle Cascade Mountains	23b Generally accordant summits; higher volcanic cones
		c Southern Cascade Mountains	23c Volcanic mountains variously eroded; no very distinct range
		d Sierra Nevada	23d Block mountain range tilted west; accordant crests; alpine peaks near east side
		a Puget Trough	24a Lowlands of diverse character; in part submerged
		b Olympic Mountains	24b Generally accordant crests; local alpine peaks
...ountain ...s		c Oregon Coast Range	24c Uplifted peneplain on weak rocks, dissected; monadnocks of igneous rock
	24 Pacific Border province	d Klamath Mountains	24d Uplifted and dissected peneplain on strong rocks; extensive monadnock ranges
		e California Trough	24e Low fluviatile plain
		f California Coast Ranges	24f Parallel ranges and valleys on folded, faulted, and metamorphosed strata; rounded crests of subequal height
		g Los Angeles Ranges	24g Narrow ranges and broad fault blocks; alluviated lowlands
	25 Lower Californian province		25 Dissected westward sloping granite upland (in northern part)

NOTE. Major divisions are separated by the heaviest lines. Provinces are named on map and also distinguished by numbers. Sections are indicated by letters. Broken lines indicate boundaries much generalized or poorly known.

Nature of the County

Physiography and Relief

Fairfax County [illegible] parts of the [illegible] Coastal Plain [illegible] the Piedmont [illegible] Coastal Plain [illegible] Coastal Plain [illegible]. From [illegible] the physiography [illegible] sections: (1) Piedmont Lowland [illegible] Piedmont Upland [illegible] Piedmont Upland [illegible] Coastal Plain [illegible] Coastal Plain, and [illegible] Coastal Plain [illegible].

The Piedmont Lowland [illegible] has an elevation of 200 to 300 feet [illegible] consisting of sandstone, shale, and conglomerate and a smaller percentage of igneous rocks [illegible] and metabasalt. The general relief [illegible] and [illegible] ridges and nearly level areas. [illegible] and steep [illegible] near large streams.

The Piedmont Lowland slopes toward the southwest [illegible] the [illegible] Piedmont Upland on the east. Cub Run, Bull Run, [illegible] Branch, and [illegible] Rocky Run drain the southern part and flow southeasterly [illegible] Creek. The [illegible] part is drained by Sugarland Run, which flows [illegible]. The drainage pattern is dendritic but is not as well developed as in the Piedmont Upland. A larger percentage of this section is flat and more poorly drained than in the Piedmont Upland [illegible] Piedmont Upland and Coastal Plain. The coarse-textured soils [illegible] section are adjacent to the Piedmont Upland because [illegible] deposited along the edge of the lakebed. The fine-textured soils are [illegible] center of the section near the Loudoun County line.

The Piedmont Upland is the largest physiographic section [illegible] percent of the county [illegible] granite [illegible] and greenstone. This section extends [illegible] the western [illegible] part of the county [illegible] Lowland. [illegible]

The Piedmont Upland is well dissected. The interstream divides are fairly wide and are undulating and rolling except [illegible] along the [illegible] large streams. Entrenchment along the lower tributaries of the major streams has been rapid. As a result, there are bluffs and V-shaped valleys with steep slopes that rise abruptly from the flood plain. [illegible] uplands are [illegible] 450 feet above sea level. This section is drained by Difficult, [illegible], and [illegible] Run [illegible] Wolf Run and [illegible] Moon, and Accotink Creeks in the south.

The drainage pattern is generally dendritic [illegible] very few of the soils require artificial drainage to be suitable for cultivation. [illegible] less than 200 feet above sea level.

B5 Physiography (Cont.)

The mixed Piedmont Upland and high Coastal Plain terraces are bounded on the east by the high Coastal Plain terraces and on the west by the Piedmont Upland. This area occupies about 23 percent of the county and has an elevation of 300 to 400 feet above sea level in most places. It is along the fall line between the Piedmont Upland and Coastal Plain physiographic provinces. The soils have formed from metamorphic rocks — granite gneiss and quartz sericite schist — similar to those in the Piedmont Upland. The sedimentary deposits in which soils have formed and which overlie the Piedmont Upland are of fluvial, old alluvial, and marine origin. This sedimentary material usually occupies the broader ridgetops that have gentle to undulating slopes of less than 10 percent. The soils that developed in these sedimentary deposits occur in widely scattered areas that make up about one-half the acreage in this section.

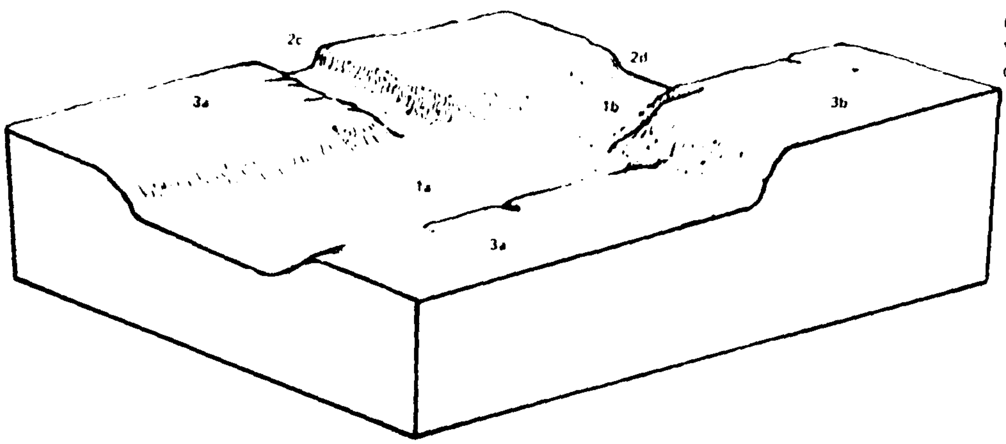
The mixed Piedmont Upland and the high Coastal Plain terraces are drained mainly by Accotink and Pohick Creeks and by Holmes and Pimmit Runs. Pimmit Run flows north into the Potomac River, and Holmes Run flows toward the southeast. The drainage pattern is generally dendritic. Steep V-shaped valleys and a few bluffs have formed where large streams have deeply dissected the uplands. A small part of the section is so poorly drained that the soils need artificial drainage before they can be cultivated. Many soils formed in fluvial and alluvial sediments have a fragipan (dense subsoil), which causes them to drain slowly.

The high Coastal Plain occupies about 22 percent of the county and is along the eastern edge. *Elevations* range from *60 to 250 feet* above sea level. This section covers two or three of the higher Coastal Plain terraces, mainly the Brandywine and Sunderland terraces, and small areas on the Wicomico terrace near the eastern boundary of the section. This section consists mostly entirely of Coastal Plain sand, silt, clay, and gravel of marine or fluvial origin that overlie Piedmont Upland material, mainly granite gneiss and sericite schist.

Between this section and the low Coastal Plain there are hilly and steep areas along the large streams and near the breaks. Most of the section consists of wide *upland ridges* that are undulating and rolling. The drainage generally is toward the southeast and is fairly well developed. It consists of Accotink Creek and the Holmes, South, and Back Lick Runs. Many slowly permeable and many gravelly soils are in the section. The acreage of wet soils needing drainage is small.

The low Coastal Plain terraces occupy about 4 percent of the county. This section is in three different areas but is mainly on the Dismal Swamp terrace at levels that are 5 to 20 feet above sea level. This *terrace* is a *young marine* deposit consisting of highly stratified and mixed sand, silt, clay, and gravel. The topography is mostly nearly level and very gently undulating, but there are small areas of rolling and hilly terrain near the large creeks and rivers. The general drainage patterns are not well developed. Most of the soils are too wet for cultivation unless they are drained artifically.

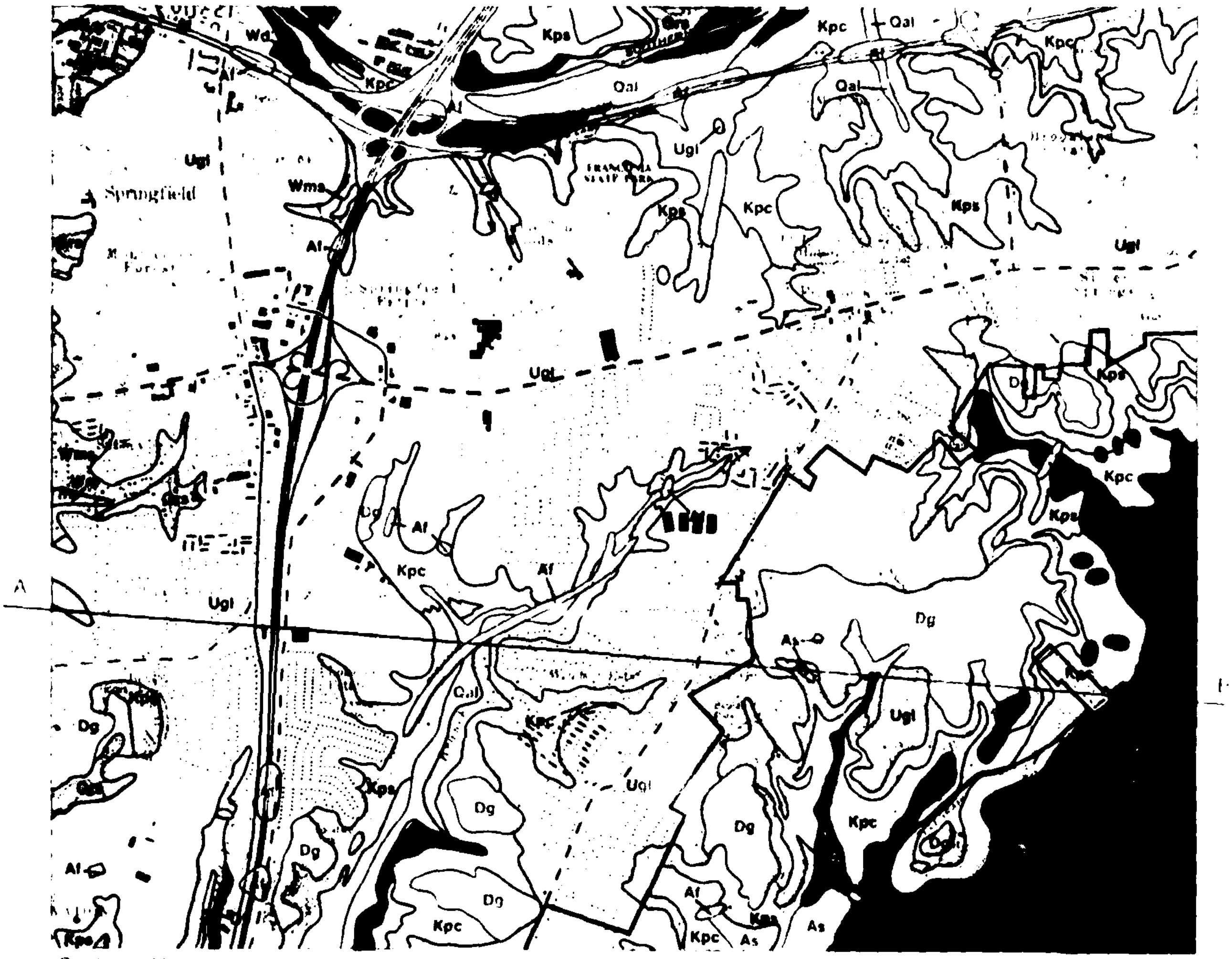
B6. Landforms



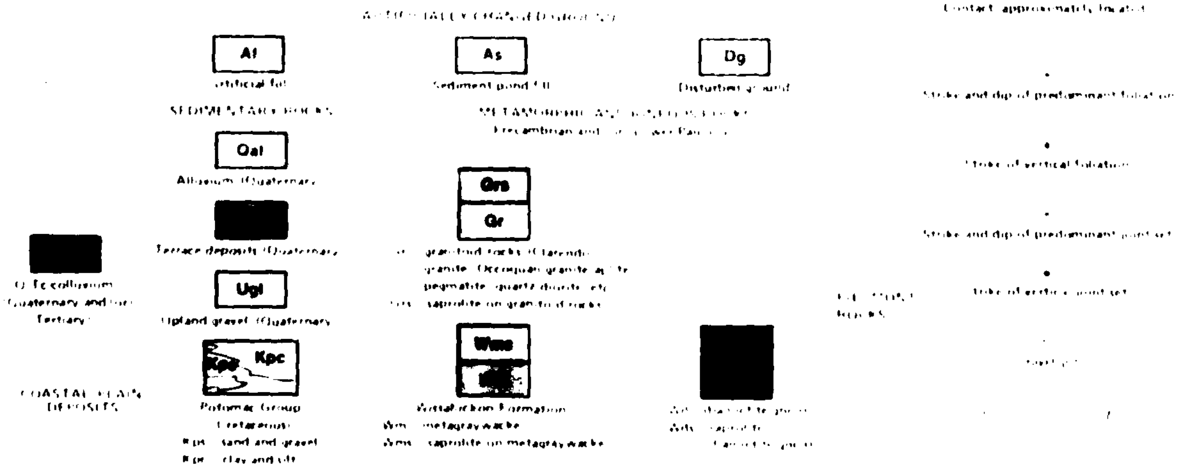
Lowlands – units 1a and 1b
Valley Walls – units 2c and 2d
Uplands – units [illegible] and 3b

Diagrammatic sketch illustrating landforms

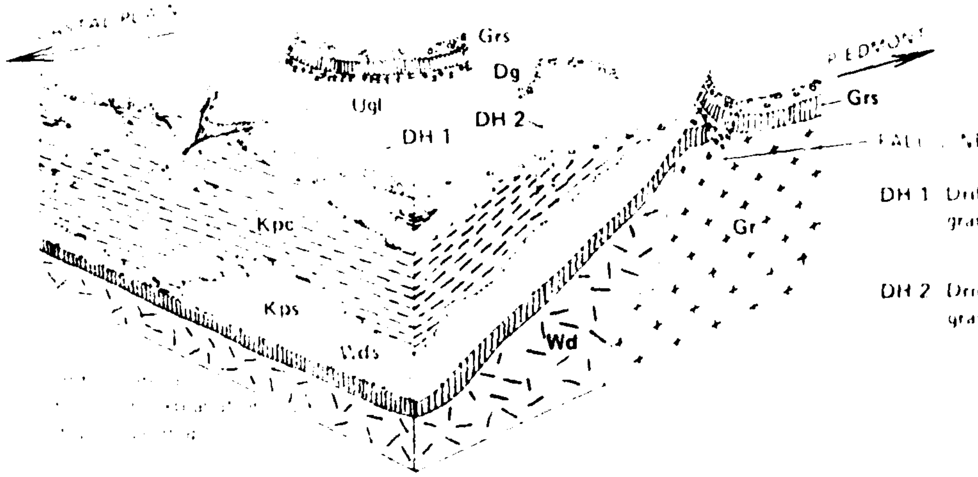
LANDFORM UNIT	SLOPES	DESCRIPTION
Uplands		
3a	Less than 3 percent	[illegible] level upland, broad open terrain marked by gravel pits, dissected by streams that have flat bottom valleys
3b	3 to 8 percent	Undulating upland dissected by streams that have cut deep valleys of varying width
3c	8 to 15 percent	Rolling to hilly uplands with locally steep slopes [illegible]
Lowlands		
1a	**Less than 3 percent**	**Nearly level flood plains of major streams, underlain by alluvium and subject to periodic flooding of varying intensity**
1b	**Less than 8 percent**	**Gently sloping plains, locally underlain by alluvium and subject to flooding by major storms**
Valley Walls		
2c	**8 to 15 percent**	**Moderately sloping valley walls, transitional between valley flood plains and the adjacent uplands**
2d	**15 percent or more**	**Includes the steeper valley walls, with slopes generally 15 – 30 percent, with maximum of 40 percent**



Geologic Map of Franconia Area



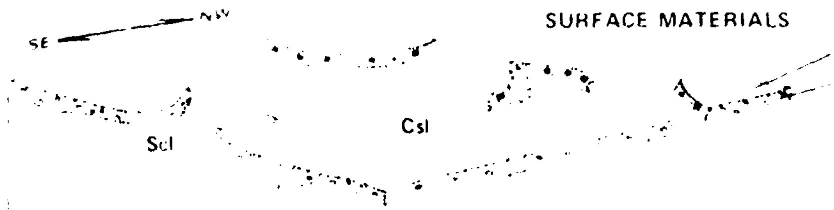
B8. Bedrock and Surface Geology



DH 1 Drill hole penetrating upland gravel and entering Kps

DH 2 Drill hole penetrating upland gravel and entering Kpc

SURFACE MATERIALS



Soils and upland gravel

Clayey silt loam (Csl) (with hardpan, poorly drained)

Sandy silt loam (Scl) (well drained)

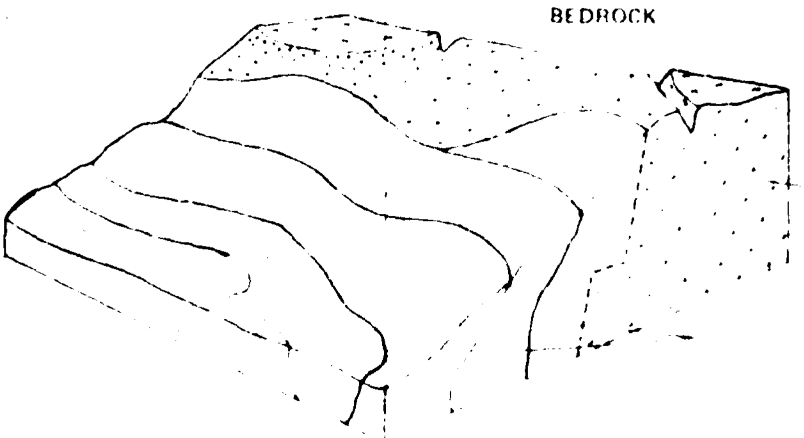
GRAVEL SUBCROP

Saprolite (Granite Gr, Gneiss Wds)

Clay (Kpc)

Sand (Kps) (ch indicates possible channel fill sands)

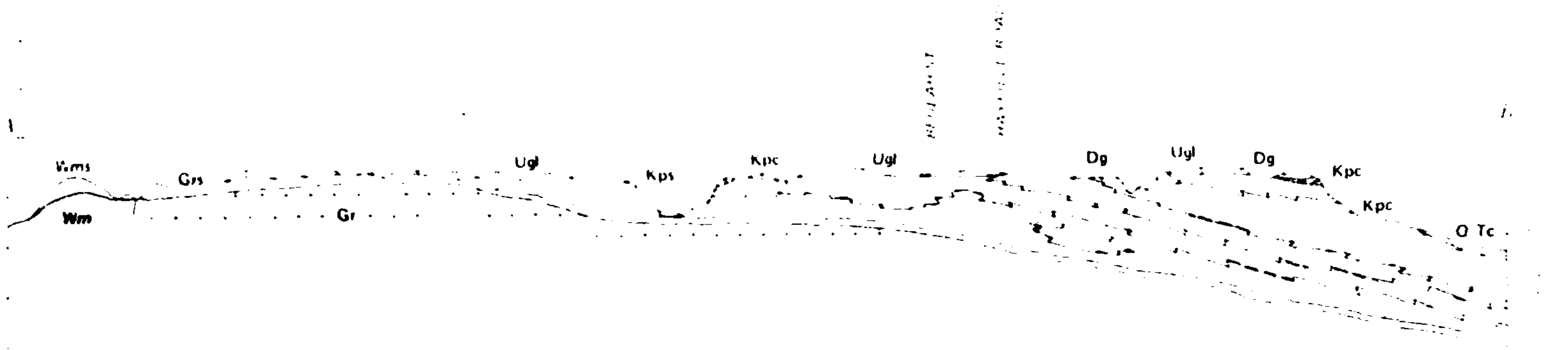
BEDROCK



Granite (Gr)

Foliated Wissahikon Gneiss (Wd)

B9. Bedrock and Surface Geology



Simplified geologic cross-section along line A-B, Franconia area

ARTIFICIALLY CHANGED GROUND

Af — Artificial fill

As — Sediment pond fill

Dg — Disturbed ground

SEDIMENTARY ROCKS

Qal — Alluvium (Quaternary)

Qt — Terrace deposits (Quaternary)

Ugl — Upland gravel (Quaternary)

Q Tc — Q Tc colluvium (Quaternary and/or Tertiary)

COASTAL PLAIN DEPOSITS

Kps Kpc — Potomac Group (Cretaceous)
Kps — sand and gravel
Kpc — clay and silt

METAMORPHIC AND IGNEOUS ROCKS
Precambrian and/or Lower Paleozoic

Grs / Gr — Gr: granitoid rocks (Falls Church granite, Occoquan granite, aplite, pegmatite, quartz diorite, etc.); Grs: saprolite on granitoid rocks

Wms / Wm — Wissahickon Formation; Wm: metagraywacke; Wms: saprolite on metagraywacke

PIEDMONT ROCKS

Wds / Wd — Wd: diamictite gneiss; Wds: saprolite on diamictite gneiss

Contact, approximately located

Strike and dip of predominant foliation

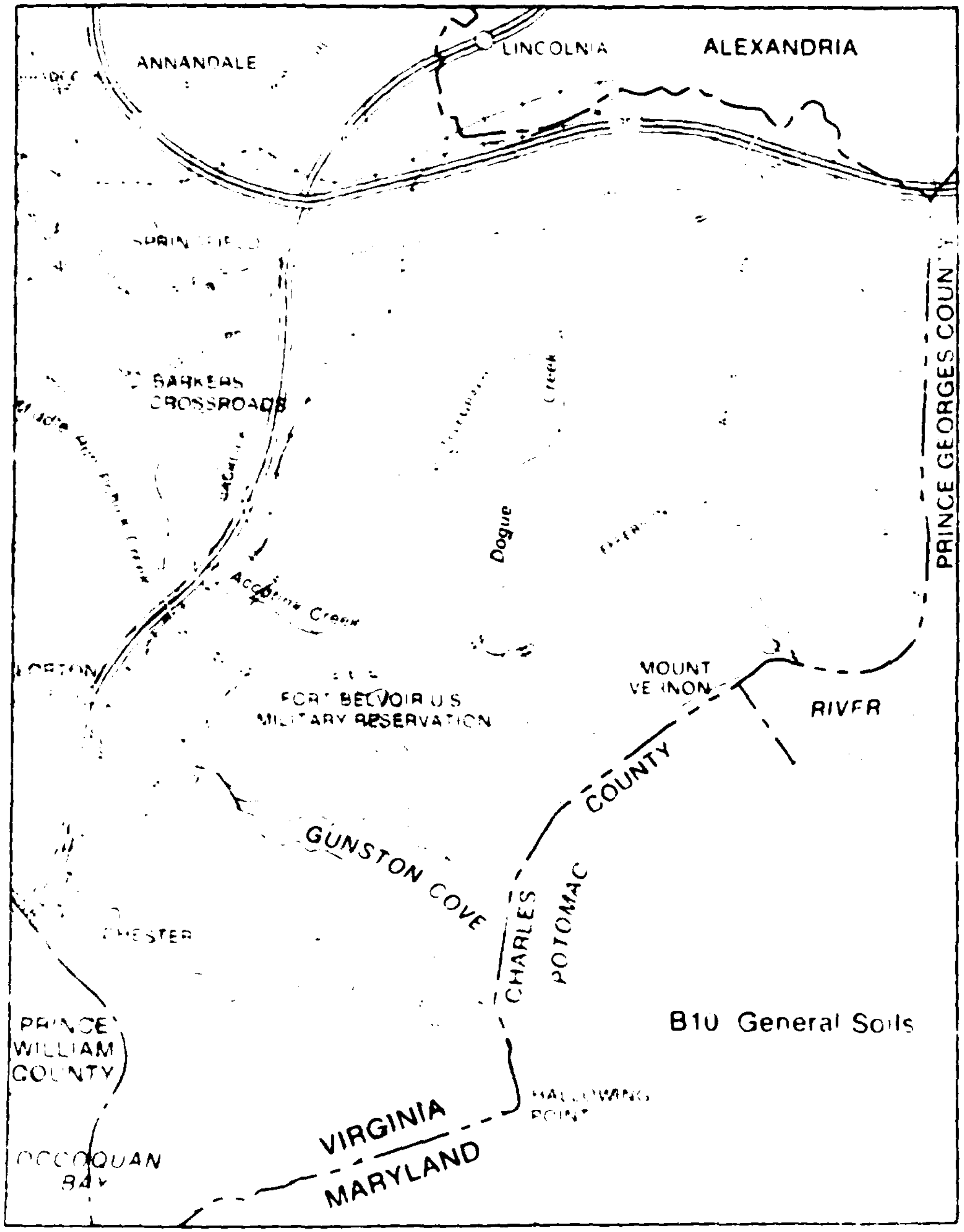
Strike of vertical foliation

Strike and dip of predominant joint set

Strike of vertical joint set

Gravel pit

Cross section (see opposite page)



B10 General Soils

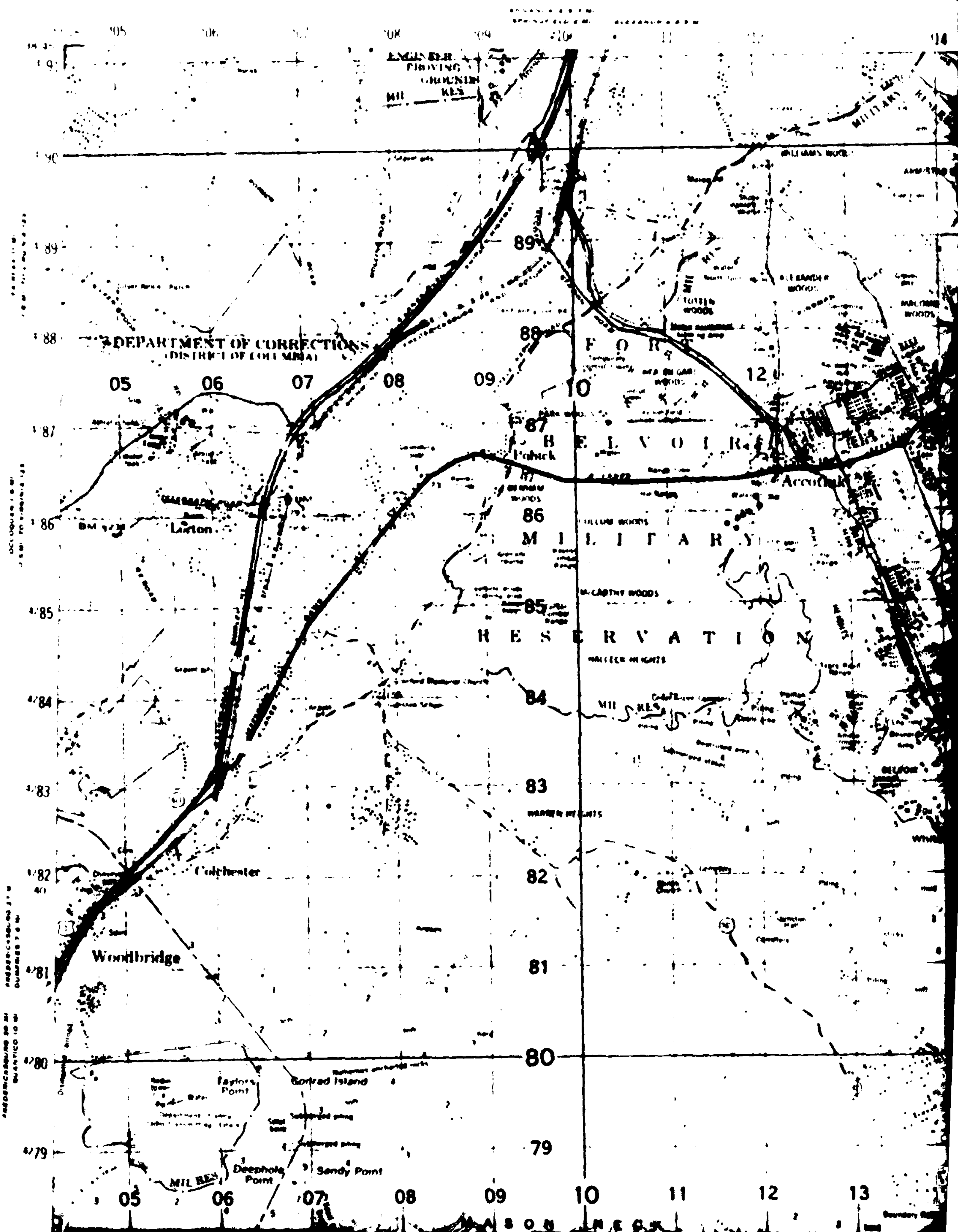
Soil Associations

SOILS ON ALLUVIAL DEPOSITS

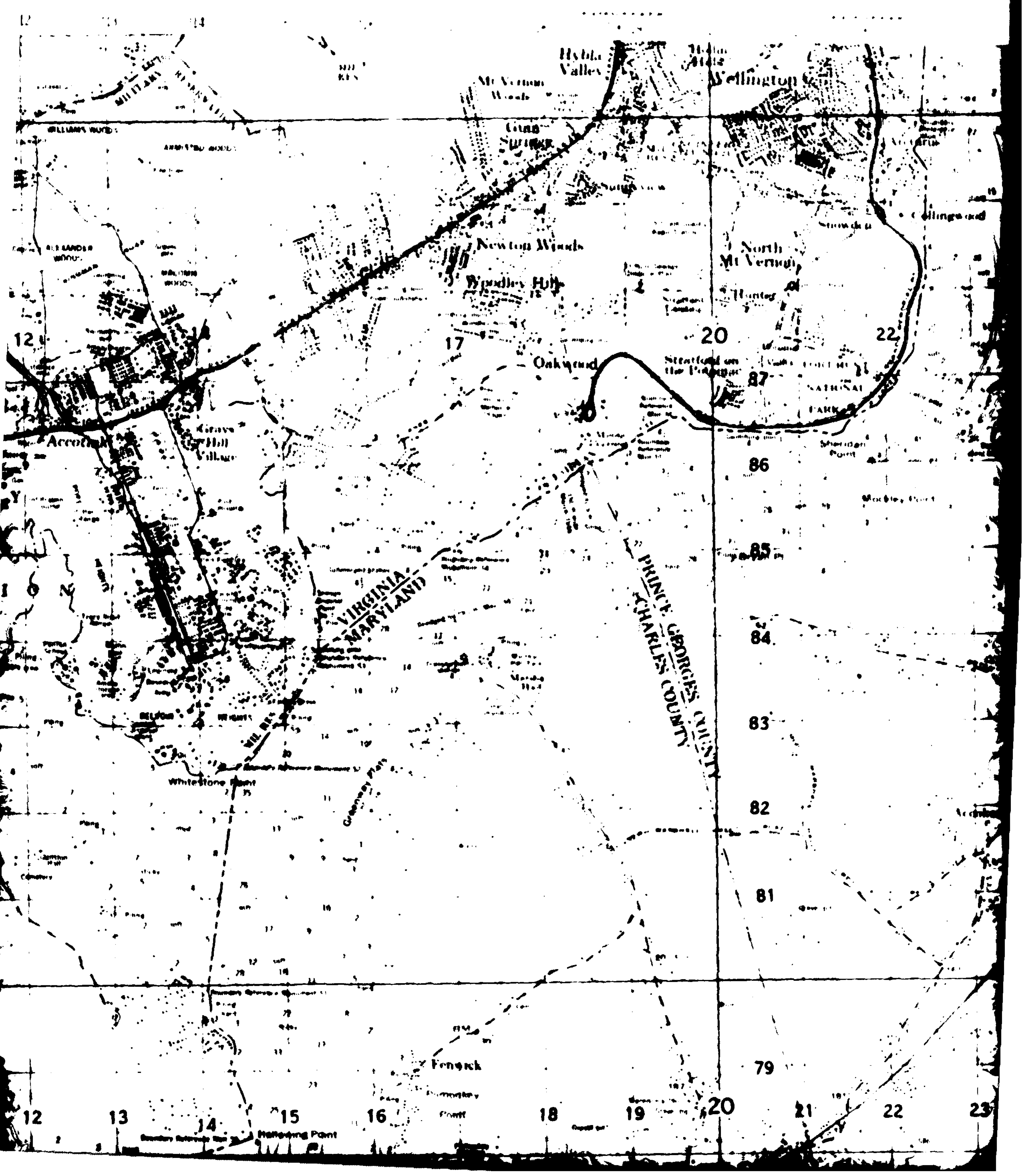
SOILS ON CRYSTALLINE ROCK OF THE PIEDMONT UPLAND

MARYLAND 1:50,000

EDITION 2-AMS



INDIAN HEAD


Hybla Valley
Wellington
Newton Woods
Woodley Hills
North Mt Vernon
Oakwood
Stratford on the Potomac
Collingwood
Accotink
Grave Hill Village
VIRGINIA
MARYLAND
PRINCE GEORGES COUNTY
CHARLES COUNTY
Whitestone Point
Fenwick
Hallowing Point
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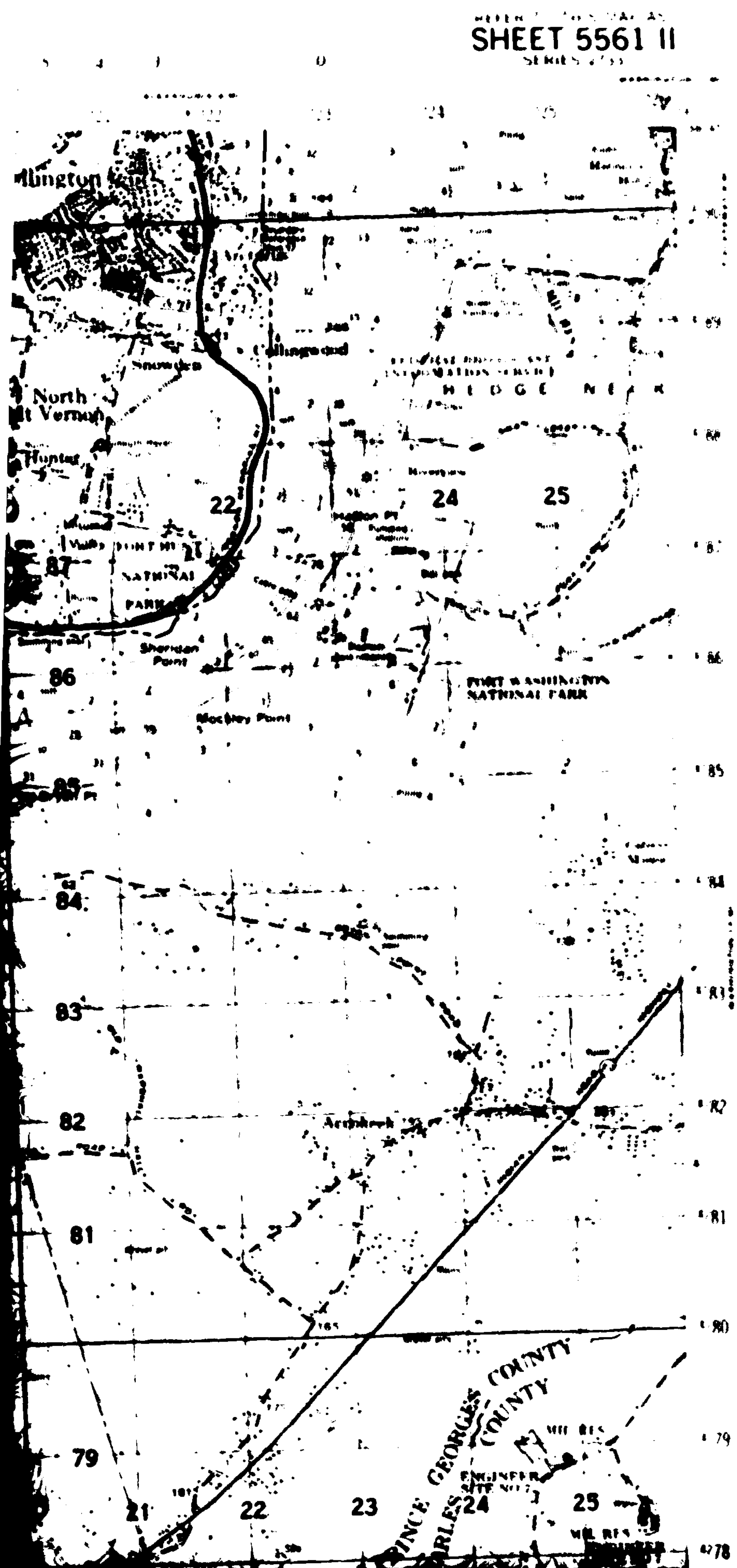
SHEET 5561 II
HEDGE NECK
North
Mt Vernon
Snowden
Collingwood
FORT HUNT
NATIONAL
PARK
Sheridan
Point
Mockley Point
FORT WASHINGTON
NATIONAL PARK
Accokeek
PRINCE GEORGES COUNTY
CHARLES COUNTY
MIL RES
ENGINEER
SITE NO 2
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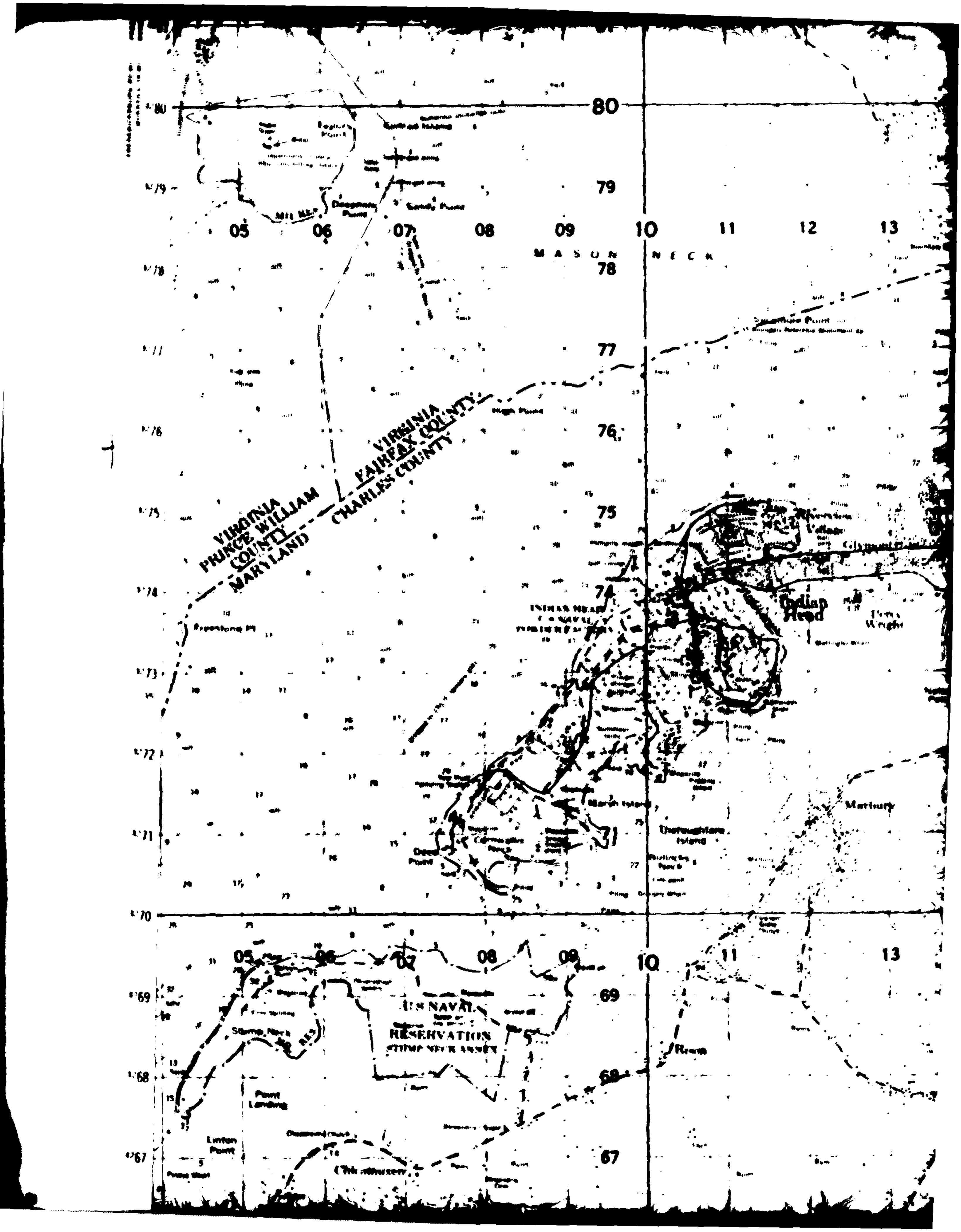
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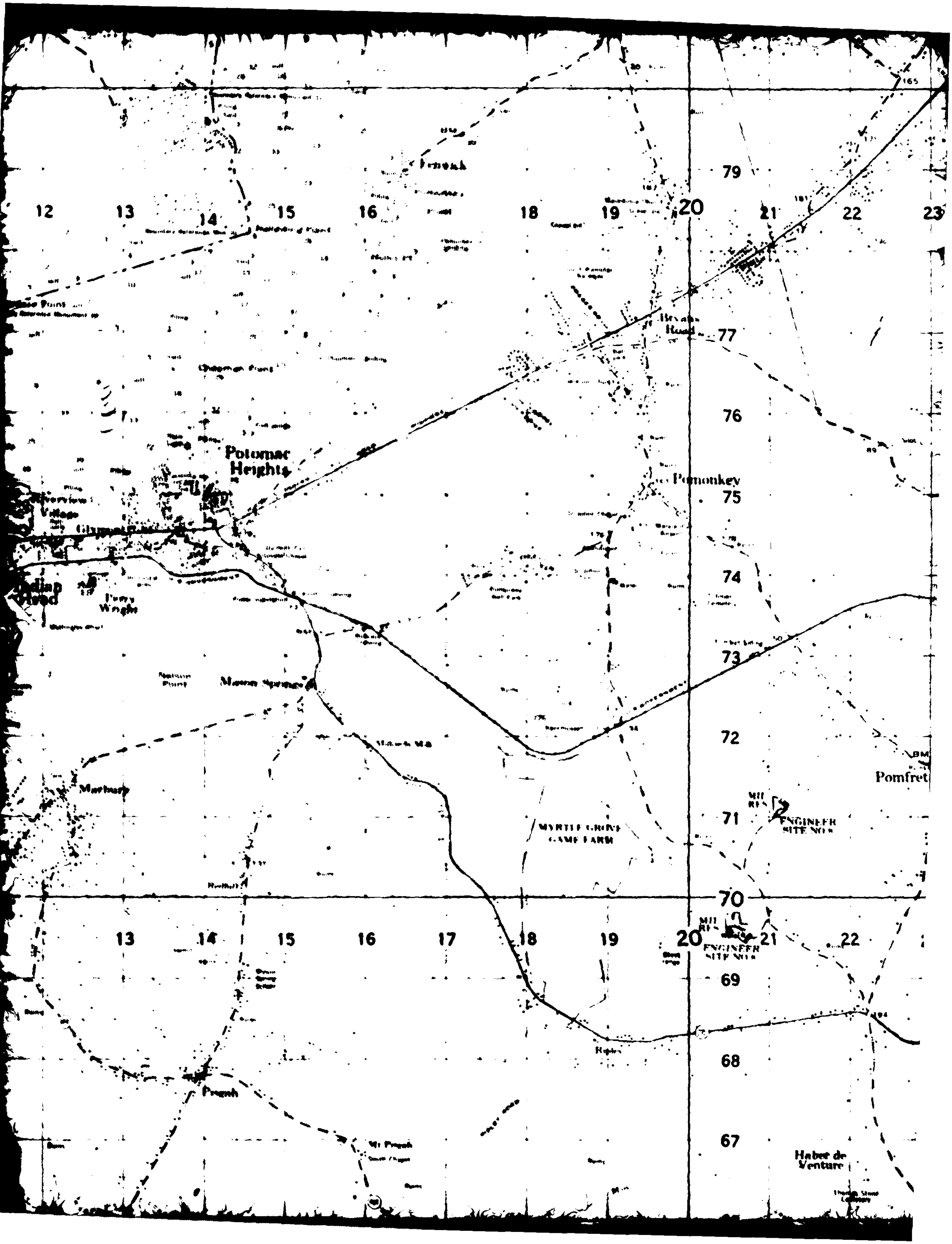
VIRGINIA
FAIRFAX COUNTY
CHARLES COUNTY
VIRGINIA
PRINCE WILLIAM
COUNTY
MARYLAND
High Point
Freestone Pt
Indian Head
Marsh Island
Marbury
U.S NAVAL
RESERVATION
Point
Linton
Point



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Potomac
Heights
Bryans
Road
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Pomonkey
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Pomfret
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MYRTLE GROVE
GAME FARM
ENGINEER
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17
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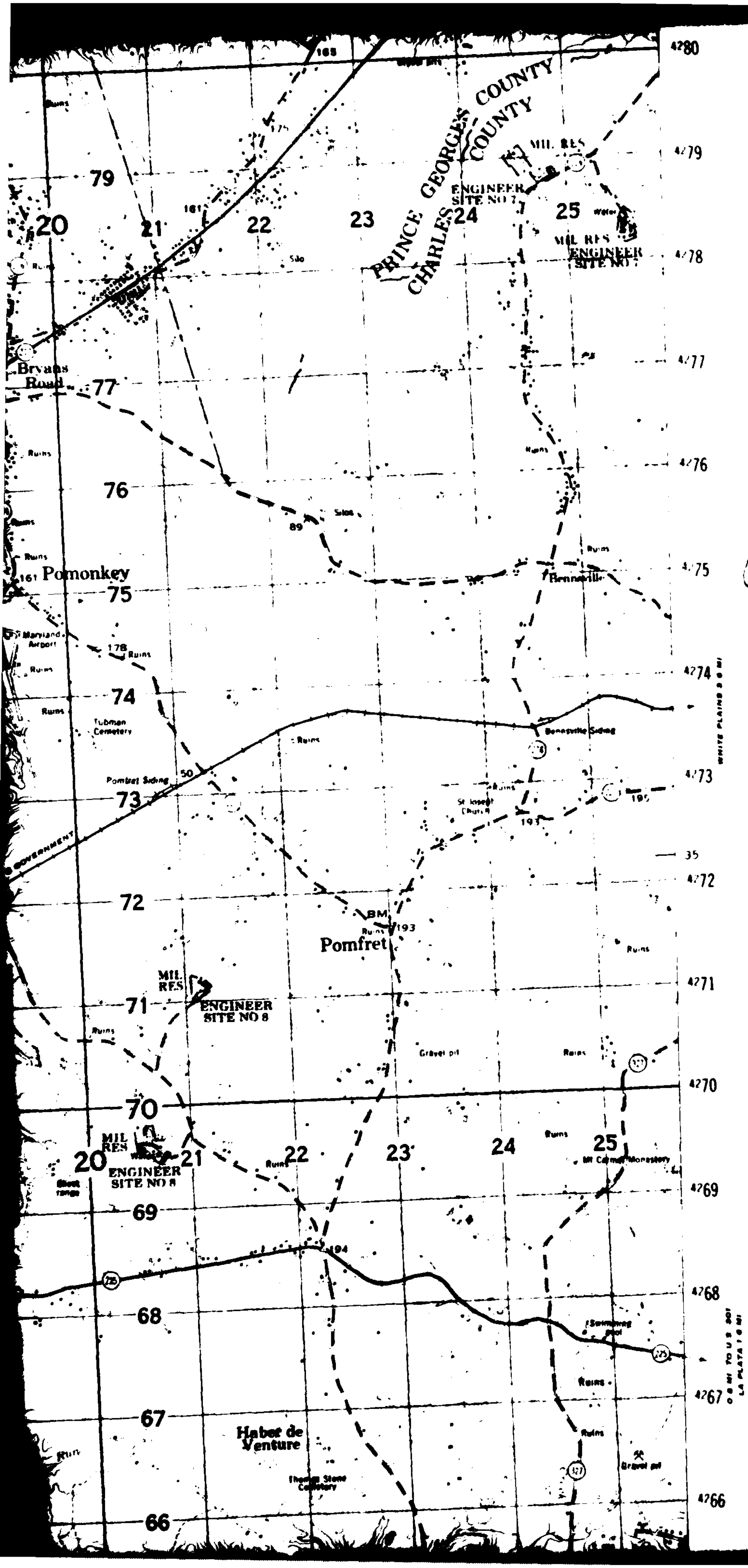
67
Haber de
Venture


PRINCE GEORGES COUNTY
CHARLES COUNTY
MIL RES
ENGINEER SITE NO 7
Bryans Road
Pomonkey
Maryland Airport
Tubman Cemetery
Pomfret Siding
GOVERNMENT
Bennsville
Bennsville Siding
St Joseph Church
Pomfret
MIL RES
ENGINEER SITE NO 8
Gravel pit
Mt Carmel Monastery
Haber de Venture
Thomas Stone Cemetery
Swimming pool
Gravel pit
Ruins
Silo
Water
WHITE PLAINS 3.0 MI
TO U S 301 LA PLATA 1.8 MI
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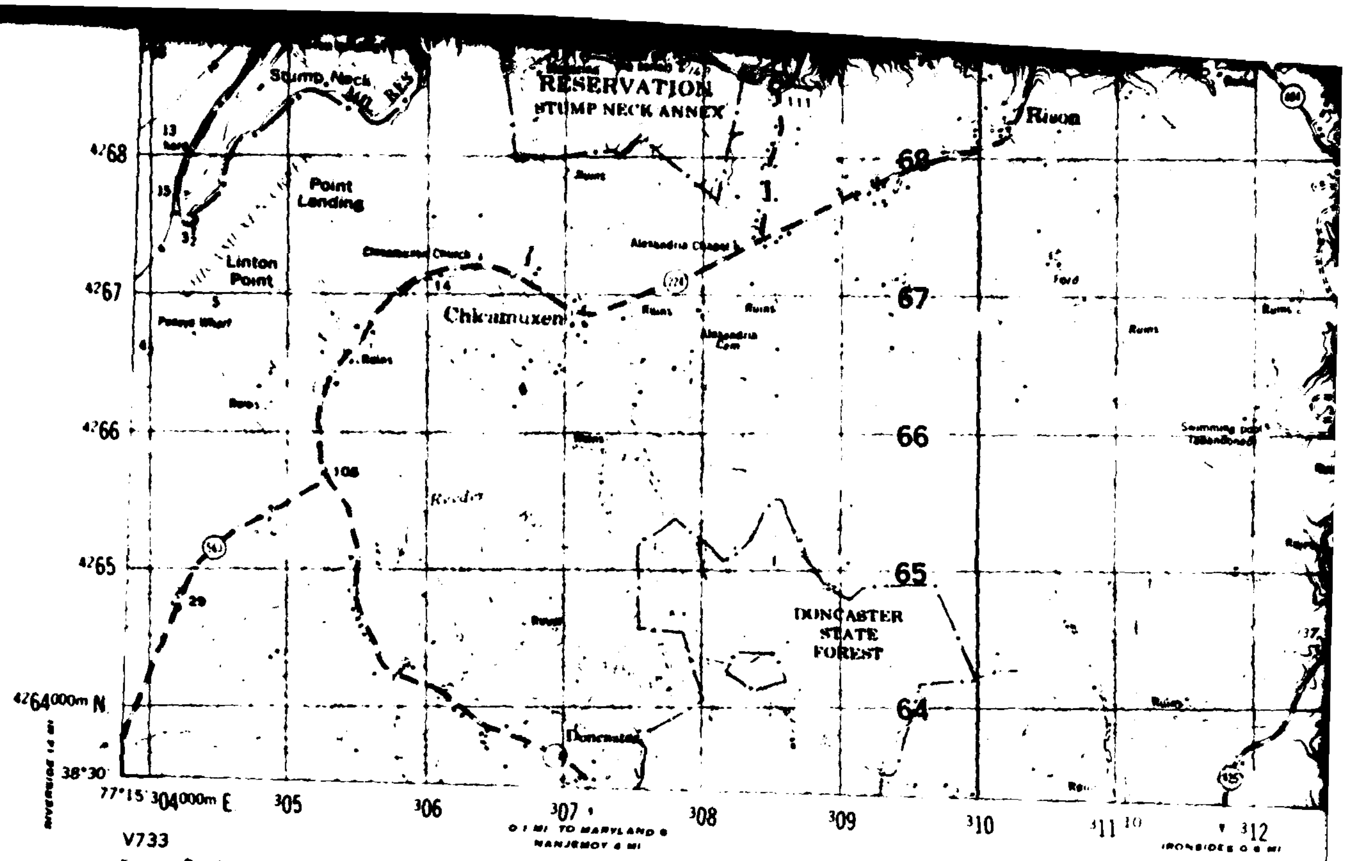


V733

Edition 2-AMS

Prepared by the Army Map Service (LD) Corps of Engineers, U. S. Army, Washington, D.C. Compiled in 1957 from Virginia, 1:25,000, AMS, Sheets 5561 II NE, NW, field checked 1956. Maryland, 1:25,000, AMS, Sheets 5561 II SE, SW, field checked 1956. Horizontal and vertical control by USC&GS, USGS and CE. This map complies with the national standard map accuracy requirements. Map not field checked. CE control established by AMS and South Atlantic Engineer Division

LEGEND

ROAD DATA 1956

In developed areas, only through roads are classified

Hard surface, heavy duty road, four or more lanes wide — 4 LANES 6 LANES

Hard surface, heavy duty road, Two lanes wide. Three lanes wide — 3 LANES

Hard surface, medium duty road, four or more lanes wide — 4 LANES 6 LANES

Hard surface, medium duty road, Two lanes wide. Three lanes wide — 3 LANES

Improved light duty road, street

Unimproved dirt road, Trail

Route markers, Federal, State

Light, lighthouse, Windmill, wind pump, Water mill

Buildings

Barns, sheds, greenhouses, etc

Intermittent lake and stream

RAILROADS — Single track — Multiple track

Standard gauge

Narrow gauge

In street

Car line

BOUNDARIES

National

State (with monument)

County

County subdivision

Corporate limits

Military reservation — MIL RES

Other reservation

Marsh or swamp, Dam

Large rapids, Large falls

Rapids, Falls, Pier

Wrecks, Exposed, Sunken

Rocks, Sunken, Awash

Soundings in feet

Depth curves in feet

Foreshore flat — Mud

Limit of danger, Reef

Man made shoreline

Spot elevations in feet

Checked — 168

Unchecked

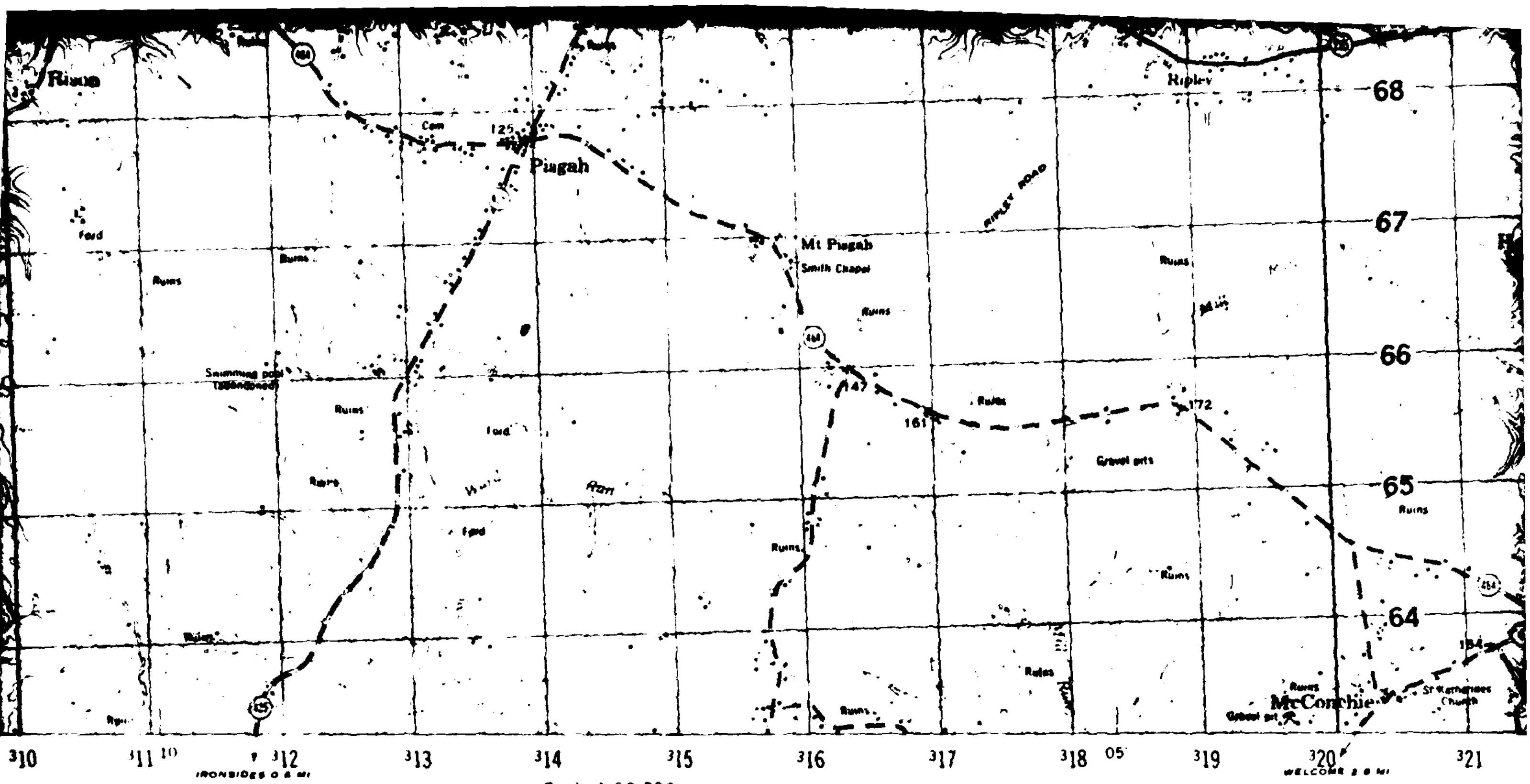
Woods or brushwood

Vineyard, Orchard

Bench mark, monumented — BM × 792

Bench mark, non monumented — × 431

7



Scale 1:50,000

1 ½ 0 1 2 3 Statute Miles

1000 500 0 1000 2000 3000 4000 Meters

1000 500 0 1000 2000 3000 4000 Yards

1 ½ 0 1 2 3 Nautical Miles

CONTOUR INTERVAL 20 FEET

VERTICAL DATUM SEA LEVEL DATUM OF 1929

TRANSVERSE MERCATOR PROJECTION

HORIZONTAL DATUM 1927 NORTH AMERICAN DATUM

HYDROGRAPHIC DATUM SOUNDINGS IN FEET REFERRED TO MEAN LOW WATER

BLACK NUMBERED LINES INDICATE THE 1,000 METER UNIVERSAL TRANSVERSE MERCATOR GRID ZONE 18

THE LAST THREE DIGITS OF THE GRID NUMBERS ARE OMITTED

USERS NOTING ERRORS OR OMISSIONS ON THIS MAP ARE URGED TO MARK HEREON AND FORWARD DIRECTLY TO COMMANDING OFFICER ARMY MAP SERVICE WASHINGTON D C MAPS SO FORWARDED WILL BE RETURNED OR REPLACED IF DESIRED

GRID ZONE DESIGNATION

18S

100,000 M SQUARE IDENTIFICATION

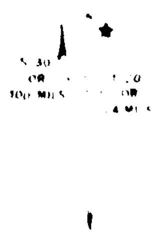
UT

IGNORE the SMALLER figures of any grid number; these are for finding the full coordinates. Use ONLY the LARGER figures of the grid number. example: 4264000

TO GIVE A STANDARD REFERENCE ON THIS SHEET TO NEAREST 100 METERS

SAMPLE POINT: ALEXANDRIA CHAPEL

1. Read letters identifying 100,000 meter square in which the point lies.	UT
2. Locate first VERTICAL grid line to LEFT of point and read LARGE figures labeling the line either in the top or bottom margin or on the line itself.	08
Estimate tenths from grid line to point.	2
3. Locate first HORIZONTAL grid line BELOW point and read LARGE figures labeling the line either in the left or right margin or on the line itself.	67
Estimate tenths from grid line to point.	3
SAMPLE REFERENCE	UT082673
If reporting beyond 18° in any direction, prefix Grid Zone Designation as:	18SUT082673

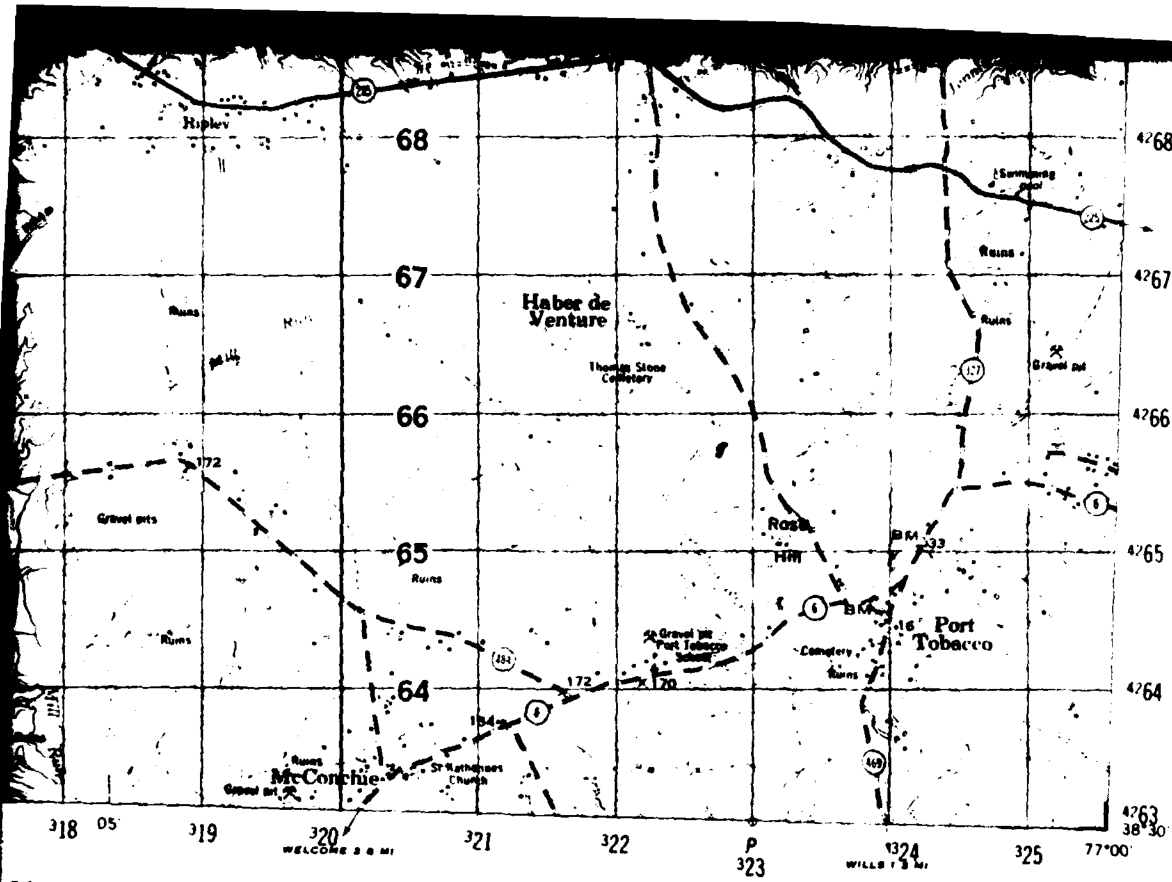


APPROXIMATE MEAN DECLINATION 1960 FOR CENTER OF SHEET

ANNUAL MAGNETIC CHANGE 2' WESTERLY

Use diagram only to obtain numerical values. To determine magnetic north line, connect the pivot point "P" on the south edge of the map with the value of the angle between GRID NORTH and MAGNETIC NORTH, as plotted on the degree scale at the north edge of the map.

8

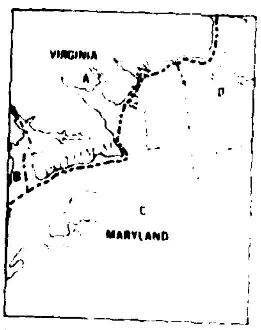


3 Statute Miles

3 Nautical Miles

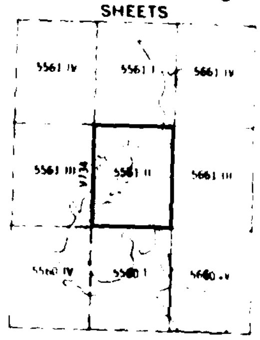
2-62 PRINTED BY ARMY MAP SERVICE, CORPS OF ENGINEERS.

INDEX TO BOUNDARIES

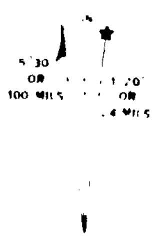


Virginia
A Fairfax County
B Prince William County
Maryland
C Charles County
D Prince Georges County

INDEX TO ADJOINING SHEETS



Sheet 5561 II falls within NJ 18-4 V501 1:250 000



APPROXIMATE MEAN DECLINATION 1980
FOR CENTER OF SHEET
ANNUAL MAGNETIC CHANGE 2' WESTERLY

Use diagram only to obtain numerical values. To determine magnetic north line, connect the pivot point P on the south edge of the map with the value of the angle between GRID NORTH and MAGNETIC NORTH as plotted on the degree scale at the north edge of the map.

FOR SALE BY U. S. GEOLOGICAL SURVEY, RESTON, VIRGINIA 22092

INDIAN HEAD, MD.; VA.

Vegetation

Fairfax County was originally covered entirely by forests of hardwood trees mixed with scattered Virginia pine and redcedar. Small quantities of hemlock were scattered along Occoquan Creek and Occoquan Bay in the southern part of the county. Yellow-poplar and other hardwood trees grew mostly on the lower Coastal Plain and on cool sites in the Piedmont Upland. Oaks mixed with scattered Virginia pine grew on the drier sites on the upper Coastal Plain and Piedmont Upland. Chestnut was common on the friable Manor, Glenelg, Appling, and Elioak soils in the Piedmont Upland and on the hilly, gravelly soils of the higher lying Coastal Plain. Oak, scattered pine, and redcedar were most abundant in the Piedmont Lowland. Most of the timber from pioneer clearings was rolled into piles and burned, except for the small part that was used as material for the necessary farm buildings.

About 40 percent of the county area is now in forest, which is widely distributed over the county. The largest and most continuous areas of forest are in the Coastal Plain and Piedmont Upland provinces in the southeastern part of the county. The Piedmont Lowland has the highest percentage of cleared land, and very little, if any, virgin timber remains. Most woodland consists mainly of white, red, pin, black, post, blackjack, and chestnut oaks and hickory, maple, beech, poplar, black locust, sassafras, dogwood, gum, and holly. There are a few scattered, pure stands of Virginia pine. A few patches of hemlock are in the southern part of the county along Occoquan Creek and Occoquan Bay. Chestnut sprouts growing from old tree stumps are found mainly in the Piedmont Upland. The poorest woodland is generally on the higher Coastal Plain soils that contain fragipans and on the Piedmont Lowland soils that have a fragipan and claypan, or that are shallow over hard rock.

The kind and quality of trees are an expression of the soil and moisture condition of the site. In places there is a direct correlation between the soils and the species of trees that grow in them naturally.

Pin oak grows in almost pure stands in the wet, flat, fine-textured Elbert and Croton soils of the Piedmont Lowland. Scrubby white oak, with a large percentage of blackjack and post oaks, grows on the heavy, clayey Iredell and Kelly soils in the Piedmont Lowland. Red and white oaks grow into large, tall trees on the deep, friable, well-drained Elioak, Glenelg, and Bucks soils. However, the same species are short bodied and slow growing on the shallow, droughty Penn and Catlett soils.

White and red oaks and yellow-poplar grow into the best, long-bodies trees in the county on the deep soils of the Coastal Plain. These deep soils have good moisture conditions for trees and are underlain by strata of sand. Chestnut oak or scrubby, short-bodied white, red, and post oaks grow mainly on the Beltsville soils, which have a fragipan 16 to 20 inches below the surface. Sycamore, river birch, boxelder, white elm, and willow are the most common species on the Chewacla and Wehadkee soils and on Mixed alluvial land of the flood plains.

Trees grow at different rates on the various exposures of a site. Chestnut oak grows poorly on some of the rocky and shallow soils on ridges. However, it grows tall and produces good timber on the East- and north-facing slopes and in moist coves occupied by the Meadowville, Manassas, and Glenville soils.

The understory in forests consists mainly of laurel, huckleberry, spicebush, wild grape, running cedar, azalea, greenbrier, mountain-tea, serviceberry, red-osier, redbud, sumac, and dangleberry.

B12. Vegetation (Cont.)

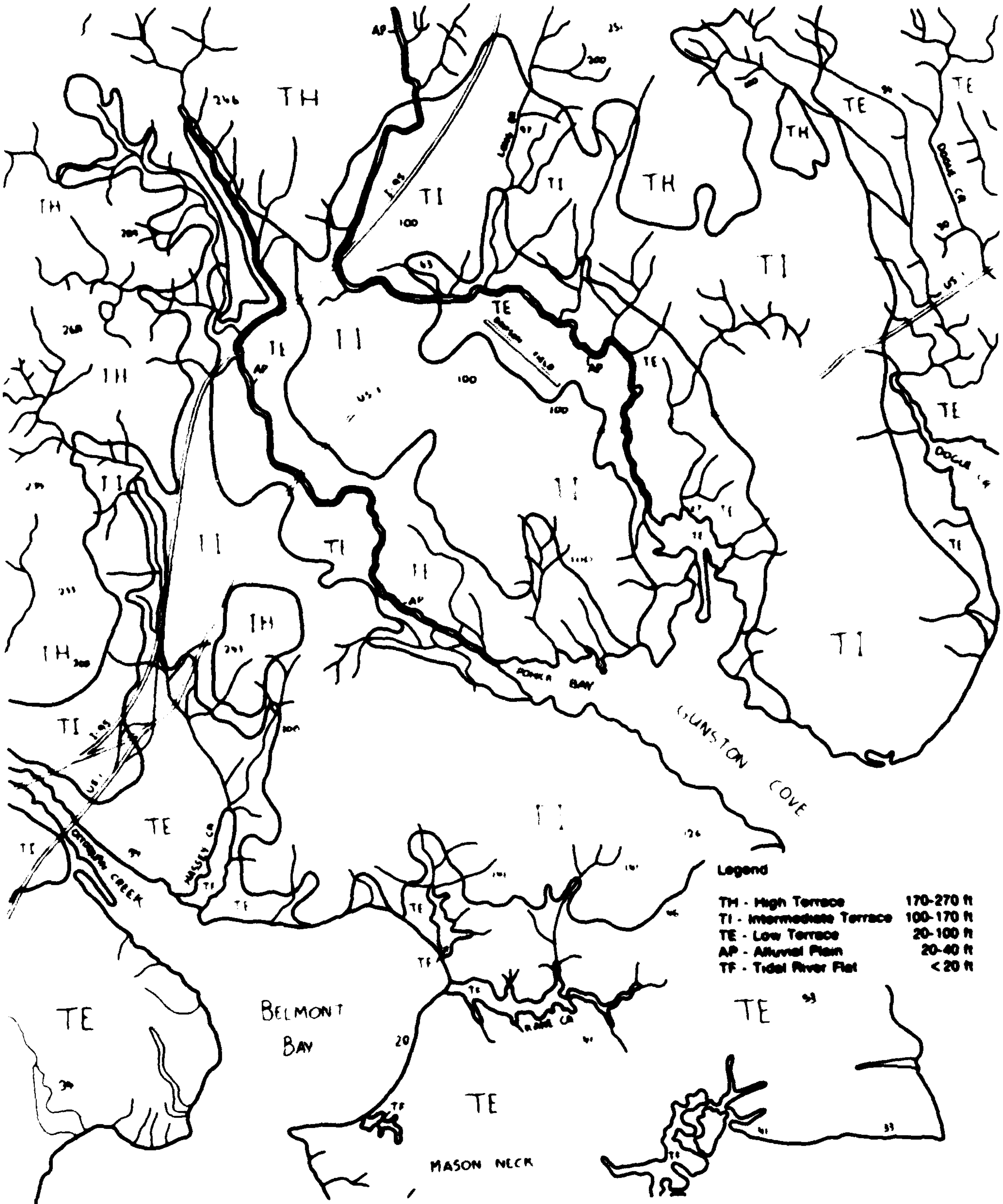
The species and growth of grasses and weeds vary on the different soils according to management. Idle fields contain many plants, including broomsedge, dewberry, blackberry, cinquefoil, hawkweed, ragweed, aster, greenbrier, sumac, orchardgrass, bluegrass, whiteclover, wild onion, beggarweed, stickweed, yarrow, oxeye daisy, sourgrass, sheep sorrel, Spanish needle, crabgrass, lespedeza, and narrowleaf plantain.

Properly managed permanent pastures generally consist mainly of bluegrass, whiteclover, and crabgrass. In addition, there usually is some redtop, orchardgrass, hawkweed, narrowleaf plantain, broomsedge, and other weeds and grasses in the mixture. Temporary pastures used in long cropping systems consist mostly of orchardgrass, but they have some fescue, ladino clover, timothy, lespedeza, and redtop. Chickweed is common in many alfalfa fields.

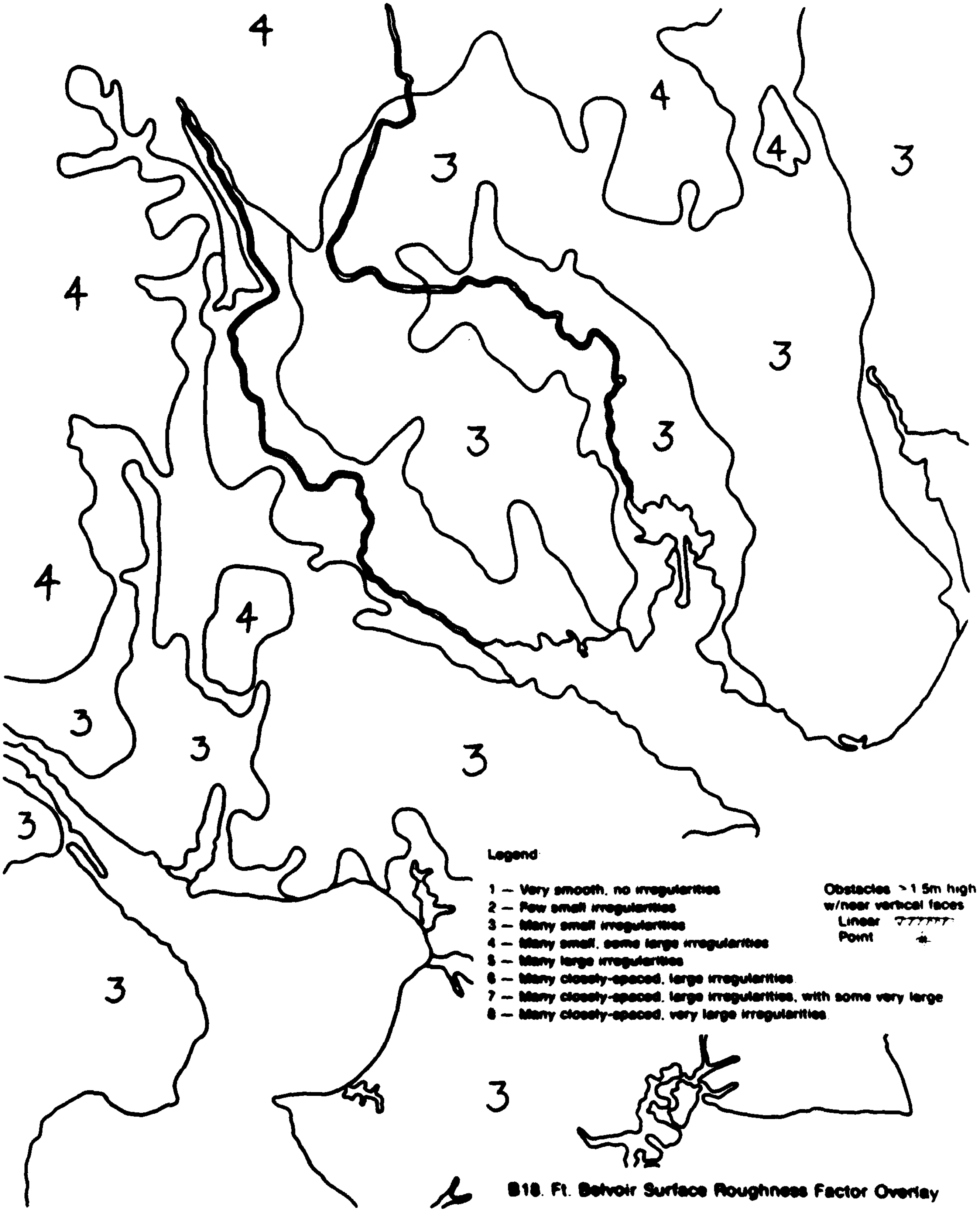
B14 Landsat MSS Band 7

B15 Ft Belvoir Air Photo Index (Uncontrolled)

B16. Ft. Belvoir Slope Factor Overlay



B17. Ft. Belvoir Landform Factor Overlay (Watercourses, Spot Elevations & Selected Roads Added)



B18. Ft. Belvoir Surface Roughness Factor Overlay

DATE

FILMED